2. METHODOLOGY FOR DATA COLLECTION AND COMPILATION

This section describes the methods by which the waste inventory information was identified, collected, compiled, reviewed, and entered into a database.

2.1 Overview

The first step in a risk assessment is to identify and quantify all radiological and nonradiological contaminants in the waste with the potential to harm humans or the environment.

Waste disposal at the SDA began in 1952. Disposal requirements and practices at that time did not include the current requirements for waste characterization. Certainly, it was not envisioned at that time that the information provided about the waste would be used later to perform a formal risk assessment; therefore, complete information about the waste was not obtained when it was generated and disposed of. However, as discussed later in this section, inventory information that is sufficiently comprehensive and reliable to support a risk assessment can be and has been compiled.

Contaminants are often identified through a sampling and analysis program. Drilling, sampling, and analysis to determine an appropriate SDA inventory is not considered feasible or practical for several reasons: (a) the area is quite large, (b) drilling into disposal units containing radioactive waste is hazardous, and (c) the contaminants are distributed unevenly over the area in concentrated and dilute form. Even a massive drilling and sampling campaign would not result in an inventory in which high confidence could be placed because of the heterogeneity of the waste.

Information and inventories concerning the waste buried at the SDA have been compiled in many previous efforts for various uses. Some of the compilations have been entered into databases. (Sections 2.2 and 2.3 discuss existing documents and databases, respectively, that contain information on the buried waste.) Some of the compilations pertain to the entire SDA; others pertain to only 1 of the 90 disposal units addressed in this report. Most of the compilations were derived from shipping records. (Section 2.3 discusses some of the deficiencies in the shipping records.) Many of the inventory compilation efforts addressed only the radioactive component of the waste. Further, waste information obtained for one purpose often does not provide all of the parameters needed for a different purpose. After investigation, it was concluded that the existing compilations of waste inventory information were very useful, but they were not adequate to support a risk assessment of the SDA under CERCLA.

In view of the limitations of the these approaches, an information gathering approach that emphasized the use of process knowledge was devised.

First, the facilities that generated the SDA waste were divided into seven groups:

1. Test Area North (TAN)
2. Test Reactor Area (TRA)
3. Idaho Chemical Processing Plant (ICPP)

4. Naval Reactors Facility (NRF)

5. Argonne National Laboratory—West (ANL-W)

6. Rocky Flats Plant (RFP)

7. Other generators — This includes all other onsite facilities, all other offsite facilities, and decontamination and decommissioning (D&D) programs.

Figure 2-1 shows the geographic locations of waste generators at the INEL. The RFP is located near Denver, Colorado. See Section 2.4.7 for a complete list of the other offsite generators that are scattered throughout the United States.

Seven lead data gatherers were appointed to compile information on the waste from the seven generators. In nearly every case, the lead data gatherers had worked at the waste generator location where they collected data, and they were familiar with the operational activities that generated the waste. Thus, the approach was *primarily one of evaluating the waste based (where possible) on knowledge of the specific processes that generated it*, as well as on review of pertinent records, databases, and reports, rather than on simply rereviewing the shipping records.

Figure 2-2 depicts the flow of information in this approach. The rectangles represent items of information, and the ovals represent technical activities performed with the information.

The upper left portion of the figure shows the principal sources of information used by the data gatherers. The data gatherers used process knowledge and plant operating records, inventory and other reports, engineering and nuclear physics calculations, shipping and disposal records (and databases of such records), interviews with plant employees (including retired employees), and other records.

The next question was the level at which the waste should be characterized. The goal was to divide a generator's waste, for data-gathering purposes, so that the resulting information could be applied to the risk assessment. Characterizing waste at the generator level would not provide sufficient detail because the waste varied greatly in form, constituents, and characteristics. Characterizing each waste container individually was not feasible. Even if information were available on the contents of each waste container (which it is not), hundreds of thousands of containers were involved.

The approach used was to divide the waste from a given generator into "waste streams." (Dividing the waste into streams was strictly for convenience in organizing the data and did not in any way restrict the data that could be gathered.) Although the definition used in this report for a waste stream is flexible, the term generally refers to a collection of waste containers with similar contents. In some cases, waste streams could be defined that were fairly uniform from one container to another. For example, all of the benelex and plexiglass from the RFP were defined as one waste stream, and all of the beryllium reflectors from TRA were defined as one waste stream. On the other hand, for a minor building that produced a very small amount of assorted waste, all waste from the building was generally grouped together into one, nonuniform stream.

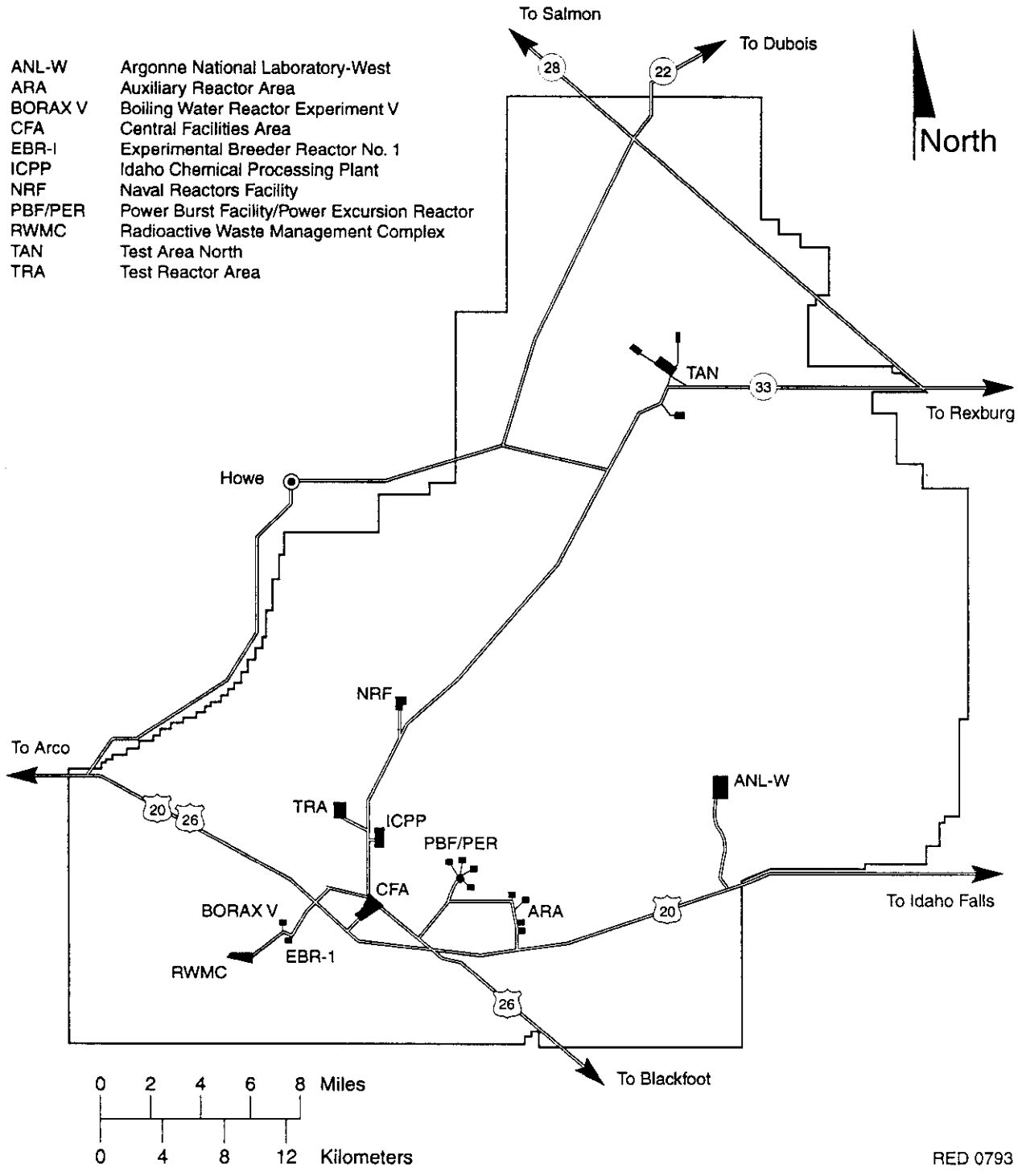

Figure 2-1. Locations of the Idaho National Engineering Laboratory waste generators in 1952 through 1983 and the location of the Radioactive Waste Management Complex.

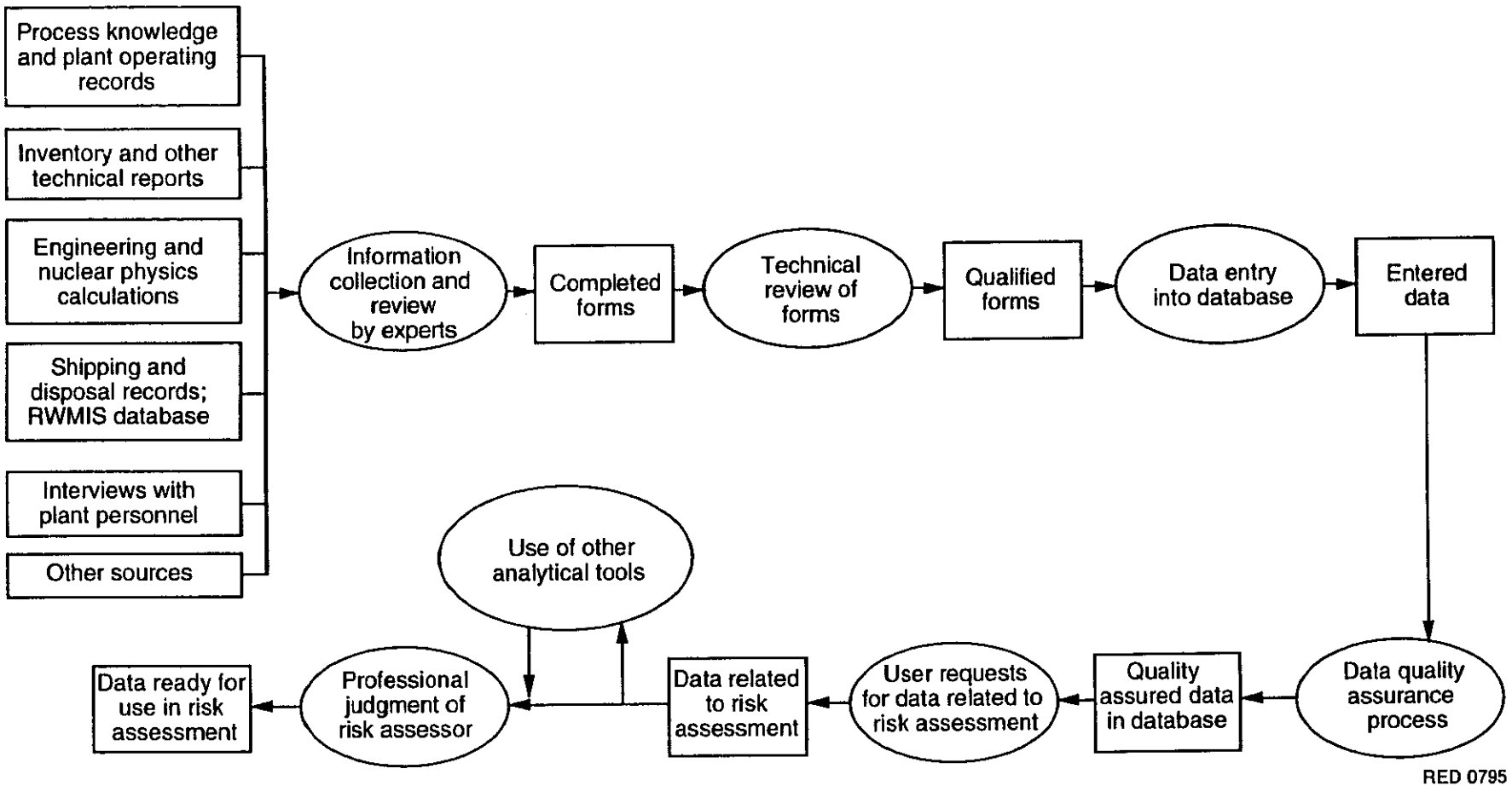

Figure 2-2. Approach for information flow in developing the inventory.

Applying this approach led to dividing the waste from a major generator into anywhere from 8 to 111 waste streams. The total number of waste streams was 234, a manageable number.

A standardized, five-page data form (see Appendix A) was used to record the information collected for each waste stream. The form indicates the generator, building, and assigned number of the waste stream from that building; the volume, physical and chemical form, and containment of the waste stream; the quantities (including uncertainties) and physical and chemical form of the nonradiological and radiological contaminants in the waste stream; the source(s) and reliability of the information; and the assumptions made in dealing with the waste stream. The form (plus continuation pages as needed) was completed for each of the 234 waste streams that were identified.

Many of the information items on the data forms were computer-searchable data fields with prescribed lists of possible answers. However, for flexibility in describing the waste, the forms included several "free" fields where verbal descriptions could be entered to an appropriate level of detail. Although free fields cannot be rolled up using the database, some of the information is invaluable in understanding subtle characteristics of the waste that affect parameters such as the mobility of the contaminants.

Candidate nonradiological and radiological contaminants for Parts C and D of the data forms (see Appendix A) were addressed as follows. All radionuclides identified in the waste streams were included on Part D. Candidate nonradiological contaminants for Part C were addressed by screening against two lists. One list consisted of the hazardous substances designated by the EPA under CERCLA. The list included chemicals designated under the Federal Water Pollution Control Act, Solid Waste Disposal Act, Clean Air Act, Clean Water Act, RCRA, and Toxic Substances Control Act. The second list covered contaminants listed in the National Primary Drinking Water Standards of the Safe Drinking Water Act. If there was any question about whether to include a nonradiological contaminant, it was included. One class of nonradiological contaminants not included on Part C was metals commonly found in alloy form in structural components, i.e., nickel and chromium, which are used in stainless steel. A literature review and analysis (Weidner 1993) indicated that, considering the extremely slow corrosion rate of stainless steel in the RWMC soil and the very limited solubility of nickel and chromium at the pH of interest, the mobility of these chemicals is expected to be extremely limited.

The steps in Figure 2-2 are discussed in more detail in the remainder of Section 2. Section 2.2 discusses the use of source documents. Section 2.3 describes the use of an existing database of shipping and disposal records. Section 2.4 provides a detailed description of how the waste information was obtained for each waste generator.

After the information was collected and entered onto data forms, it was subjected to a qualification process (discussed in Section 2.5) and entered into a contaminant inventory database for risk assessment (described in Section 2.6). Finally, with the use of other analytical tools and the professional judgment of risk assessors, the data are ready for use in risk assessments.

2.2 Use of Source Documents

As indicated in Figure 2-2, technical reports and other documents containing inventory and related information about the waste buried in the SDA were one of the primary sources of information

collected in this study. This section discusses the types of reports available and describes how the reports were used.

A large number of documents contain useful information about the waste buried in the SDA. The documents range from brief letters to comprehensive technical reports. The scope of the documents ranges from narrow (addressing only one waste stream from one generator) to comprehensive (fairly complete inventories), although none of the documents covers the full scope required for the BRA. Some of the documents are devoted solely to discussions of inventory, while others address inventory only briefly as part of another topic, such as the characteristics of waste to be processed in a proposed treatment facility. Many of the documents contain data extracted from previous documents. The dates of the documents range from the 1950s to the present. Some of the documents offer crucial information, while others are of limited value.

Because the existing documents were of considerable value to the current study, as many as possible were identified and evaluated for their applicability. Data gatherers reviewed the documents related to their assigned generator and incorporated the appropriate information into the data-gathering effort.

For each waste stream, the data gatherer specified the sources of information in Part E of the data form (see Appendix A). If a document was the source of an item of information, the box titled "reports" was marked on the data form, and the title, author, report number, and date were entered. On many data forms, the data gatherers also compared the inventory specified in a reference report against sometimes-conflicting data from other sources of information, made a judgment as to which data were considered more credible, and indicated the basis for the judgment.

More than 190 specific reports and letters are discussed and referenced in later parts of Section 2.

2.3 Use of the Radioactive Waste Management Information System

In addition to process knowledge, technical reports, calculations, shipping records, and interviews, existing databases were searched to obtain information. The principal databases accessed in the current task were the Radioactive Waste Management Information System (RWMIS) and the accompanying Qualifier Flag/Additional Contents database.

2.3.1 Description of RWMIS

RWMIS (Litteer 1988) is a mainframe electronic database developed in 1971, which resides on an IBM 3083 computer. Information reported in RWMIS includes all airborne (onsite effluent), liquid, and solid radioactive waste shipped to or generated at the INEL. RWMIS provides an inventory of radioactive waste stored or disposed of at the RWMC and radioactive effluents generated at the INEL.

The data in RWMIS originated from shipping and disposal forms[a] that accompanied the waste when it was shipped for storage or disposal.

The database consists of *summary* waste shipping and disposal records for the years 1954 to 1970 (nothing from 1952 to 1954), *waste shipment* records for 1971 to 1986, and *container-by-container* records from 1986 to the present. Shipment-specific waste information data before 1971 are not included in the user-accessible database. These pre-1971 records are referred to as the Best Available Data (BAD) database. Records in RWMIS for 1971 to 1983 and 1984 to the present are referred to as the historical database and the current database, respectively.

RWMIS is a hierarchical database consisting of a parent-master (shipment information) and two children: a nuclide information child and a container information child. The parent-master has a one-to-many relationship with the nuclide and container information children.

Table 2-1 lists and describes the primary fields in RWMIS.

2.3.2 Verification of RWMIS; the Qualifier Flag/Additional Contents Database

RWMIS data were verified in 1992 by comparing the original shipping manifests that accompanied the waste shipments with the corresponding fields on printouts of the RWMIS database. RWMIS data for waste disposed of in the following pits and trenches at the RWMC were verified:

- Pits 2–16
- Trenches 17–58

Data for the following locations were not verified:

- Soil vault rows
- Pits 1 and 17–20
- Trenches 1–16.

During the verification process, an additional database (the Qualifier Flag/Additional Contents database) was created to capture information not included in RWMIS. The database contains an inventory of the specific discrepancies between the RWMIS printout and the shipping manifest. It also documents the additions or deletions to the RWMIS content code required to reflect the contents of the waste specified on the shipping manifest. This information was captured using a prespecified set of codes.

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a. For simplicity, shipping and disposal forms are generally referred to as "shipping records."

Table 2-1. Primary information fields in the RWMIS database.

Primary RWMIS fields	Description
Waste origin	The site (area and building/location) at which the waste was generated.
Waste type	The physical phase of the waste (i.e., liquid or solid).
Radioactive	A flag that specifies if the shipment is radioactive.
Report date	The date generally identifies the date the shipment form was completed. It usually appears on the form as the date of approval for shipping the waste.
Waste description	A generic description of the shipment. In most cases, this field also includes radiation readings taken at contact and at 1 m (3 ft) from the shipment.
Gross volume	The gross volume of the waste shipment in cubic meters.
Gross weight	The gross weight of the waste shipment in grams.
Gross curies	The gross curies in the waste shipment.
Disposal date	The date of waste disposal or storage.
Container type	The type of waste container.
Container number	The number of waste containers in the waste shipment.
Container volume	The volume of each type of waste container in the waste shipment.
Volume unit	The unit of volume for each waste type container.
Waste description	The content code that provides a generic description of the waste in the container (e.g., Code 003 implies paper, metal, and wood).
Disposal location	The disposal or storage location of the waste.
Nuclide	The isotopic nuclide designation.
Nuclide weight in grams	The gram quantity of each nuclide in the waste shipment.
Nuclide quantity	The curie quantity of each nuclide in the waste shipment.

2.3.3 RWMIS Download for the Current Task

The RWMIS, BAD, historical, and current mainframe electronic databases were downloaded from NOMAD to an IBM personal computer dBASE environment to support the HDT. The download was performed for Pits 1 through 16, Pit 17 for the years 1982 and 1983, Trenches 1 through 58, Pad A, and Soil Vault Rows 1 through 13. RWMIS contains no data for the Acid Pit.

To use RWMIS in the dBASE environment, the data were downloaded into three relational databases. These databases consisted of the master (as stored in RWMIS), a nuclide information database (with key information from the master), and a container information database (with key information from the master). A verification procedure was written and implemented to maintain the integrity of the RWMIS databases during the download. In the RWMIS mainframe environment, a count was made of the number of records, and all numerical fields were summed. The same checks were made on the download (dBASE) version of the database. All inconsistencies were resolved before the data were used.

The download version of RWMIS was used as one source of information to support the current task. As shown in Figure 2-2, RWMIS and the accompanying Qualifier Flag/Additional Contents database were useful sources of information collected by the data gatherers.

2.3.4 RWMIS Limitations

Section 2.1 indicates that existing reports and databases of SDA waste inventory information were very useful, but they are not adequate to support risk assessments conducted under the FFA/CO. This section provides more detail on why the RWMIS database could not serve as the sole source of inventory information.

For shipments before 1960, RWMIS has entries for only RFP waste (none of which are available for Trenches 11 through 15), and those entries generally provide no quantitative information concerning the contaminants. Essentially no records for onsite waste were available when RWMIS was created.

Another limitation of RWMIS is that it does not contain content codes (well-defined physical and chemical descriptions) for waste disposed of between 1971 and 1983. Textual descriptions are used to describe the contents of the waste. Some of the textual descriptions are generic (e.g., plant waste) and do not identify the actual contents of the waste. Also, many of the textual descriptions refer to more than one waste form. This makes providing summaries by waste form extremely difficult, if not impossible. Finally, several different textual descriptions may be used to identify the same waste form.

Another limitation of RWMIS is that it contains very little information concerning nonradiological contaminants in the waste.

Before 1986, RWMIS stored data only on a shipment basis. The curies (or grams) identified with each isotope were specified for the entire shipment and not for individual containers. For example, this limitation makes it difficult to determine if the contents of an individual container should be classified as TRU waste or LLW.

From a risk assessment perspective, there are several other deficiencies in the RWMIS database. These deficiencies reflect a lack of either detail or completeness. Some of these deficiencies include entries with

- Only one radionuclide identified, e.g., Pu-239, whereas knowledge of the waste-generating process indicates that other radionuclides must also be present
- Only the element specified, e.g., uranium, with no designation of a particular radionuclide
- Only MAP and/or MFP identified, with no designation of particular radionuclides
- Equal amounts of MAP and MFP identified, suggesting that no rigorous estimate of radionuclide breakdown was performed
- Only one fission product identified, e.g., Cs-137, whereas knowledge of the waste-generating process indicates that others must also be present
- Only one activation product identified, e.g., Co-60, whereas others must also be present
- Unidentified radionuclides, e.g., unidentified beta-gamma, unidentified alpha
- No chemical form specified
- No physical form specified.

2.4 Data Collection Methods

This section discusses the methods used to collect waste information for the seven waste generators. Because the waste and the available information differed among generators and waste streams, the data-collection methods also differed.

The discussion of the methods is presented in three ways. First, Sections 2.4.1 through 2.4.7 generally describe the waste generator of interest, the processes by which the waste was generated, the availability of waste information from the generator, and the data-collection approach selected.

Second, these sections also describe in detail the "most important" waste streams, by generator. Most important waste streams are defined as

> Those streams that collectively contain at least 90% (typically 98%) of the estimated total quantity of all radiological and nonradiological contaminants, based on the results of risk-based screening calculations using a draft version of the inventory.

Approximately 60 waste streams were designated as the most important streams under this definition. A few additional streams that were considered to be of interest by the data gatherers are also described in detail.

For each of these streams, the following information is provided: how the stream was generated, the principal contaminants in the stream (not necessarily in order of quantity), the sources of information about the stream, and the assumptions and analysis used in estimating the quantities of

contaminants. *If the stream helped to contribute to the 90% quantity of any radiological contaminants, then the principal radiological contaminants in the stream are listed. Similarly, if the stream helped to contribute to the 90% quantity of any nonradiological contaminants, then those contaminants are listed. If both cases apply, then both types of contaminants in the stream are listed.*

Third, information on the assumptions and the sources of information for every waste stream is available on the data forms for the various waste streams. As discussed in Section 2.6, the data forms have been entered into a database. A printout of the entire contents of the database is provided in Appendix B, Volumes 2 through 5 of this report.

The database uses an alphanumeric designator to uniquely identify each waste stream. The first part of the designator generally is a three-letter code representing the name of the major generator. The second part generally is a three-digit code representing the building number where all or most of the waste stream originated. The third part of the designator is a number representing the sequence of the waste stream identified from the given building. A suffix is added to the end of the waste stream number to indicate if the stream is historical (H), recent (R), projected (P), or Pad A (A). Only the historical streams and Pad A are within the scope of this document; recent and projected streams are addressed in a companion document LITCO (1995). Thus, the designator TRA-603-21H represents the 21st waste stream identified and characterized from Building 603 at the Test Reactor Area during the historical period.

2.4.1 Test Area North

The Generator. TAN lies at the north end of the INEL, about 43 km (27 mi) northeast of the Central Facilities Area (CFA) (see Figure 2-1). TAN was designed and constructed in the early 1950s to support the General Electric Aircraft Nuclear Propulsion (ANP) Program, the mission of which was to test the concept of the nuclear-powered airplane. For a 9-year period, until the program was canceled by the U.S. Congress in 1961, the program tested three versions of a full-scale, nuclear-powered aircraft engine (Wilks 1962). The program support facilities consisted of the Technical Support Facility (TSF), where technical support facility personnel had offices; the Initial Engine Test (IET) Facility; the Hot Shop, a large hot cell into which the engines could be moved for repair, assembly, and disassembly; and some smaller hot cells, built for the examination of individual irradiated fuel pieces or other irradiated specimens. The IET and Hot Shop were connected by a double set of rail tracks that allowed the engines to be moved back and forth.

Testing of the three Heat Transfer Reactor Experiment (HTRE) engines involved passing preheated air through the 93.4% enriched uranium core and jet engine components and releasing it to a 46-m (150-ft)-high stack (Devens et al. 1958). Each test sequence conducted in the ANP Program was designated with an IET number. The HTRE-1 engine, in which IET #3, #4, and #6 tests were conducted as a proof of principle, consisted of a reactor core of 37 fuel assemblies clad with nichrome (80% nickel and 20% chromium) (Thornton et al. 1962).

The HTRE-2 core was used for the remaining 20 IET tests except #13, #16, #18, and #25, and lasted from February 1957 to March 1961. A central test location was used to test various fuel/ceramic configurations (Flagella 1962). All but one of these tests involved a fuel/ceramic configuration of beryllium oxide (BeO). The remaining nonceramic test, IET #15, was an endurance testing sequence involving a Cr-UO_2-Ti (metallic), concentric-ring, fueled insert (Evans 1959).

The HTRE-3 engine, designed for the actual airplane, was used to confirm operational parameters and endurance characteristics for the core (Linn et al. 1962). This core was used for conducting the IET #13, #16, #18, and #25 experiments.

After the ANP Program, the TAN Hot Shop and hot cells were used on an ad hoc basis for projects that required heavy shielding.

In 1961, near the end of the ANP Program, a Stationary Low-Power Reactor No. 1 (SL-1) accident occurred at the NRTS, the former name of the INEL. The SL-1 reactor vessel was disassembled for examination at the TAN Hot Shop.

From July 1962 until the 1970s, the TAN Hot Shop and hot cells were, with four exceptions, devoted principally to the Loss-of-Fluid Test (LOFT) and miscellaneous minor examinations and tests for TRA and the Power Burst Facility (PBF). The four exceptions involved examining the two reactor cores included in the Systems for Nuclear Auxiliary Power Transient (SNAPTRAN) tests that were conducted in 1964 (Fletcher 1964; Kessler et al. 1965) and 1966 (Cordes et al. 1967; Kessler et al. 1967), the final disassembly and examination of the Mobile Low-Power Reactor No. 1 (ML-1) reactor core (Murphy et al. 1966), and the testing and examination of the Portable Medium Nuclear Power Plant (PM)-2A reactor vessel (Mousseau et al. 1967). The disassembly and examination of each of the two reactor/reactor vessel components required the disposal of radioactive material that was roughly equivalent in radioactivity to that for the SL-1 examination and disassembly. To more accurately account for the radioactive and hazardous waste that was sent to the RWMC by these projects, the TAN Hot Shop and hot cell logs were reviewed.

The SNAPTRAN tests were criticality-destruct type tests that purposely destroyed the nuclear core. The first test, in 1964, simulated a water immersion accident during launch of the power plant. The fuel-moderator was an alloy of zirconium hydride and 10 wt% of 93% enriched uranium. The small core contained U-235 in 37 fuel rods and 464 gram-moles of H_2. The core was reflected by beryllium inserts. The interstitial space among the fuel rods contained NaK.

The second SNAPTRAN test, in 1966, destroyed the core in air with the same type of destructive criticality event as in the 1964 test. This test configuration contained significantly more beryllium than the first test, but no NaK (Dietz 1966). The internal beryllium reflector in both tests amounted to about 5,500 g, and the external beryllium reflector of the second test added an additional 11,000 g of beryllium.

Beginning in 1980, the TAN Hot Shop and hot cells supported research and development of material from the Three-Mile Island (TMI)-2 reactor as a result of the 1979 accident. During the mid-1980s, the final tests for the LOFT program were supported by the Hot Shop.

Generation of the Waste. Most of the waste produced at TAN was a result of the specific test and evaluation programs discussed. The decontamination, disassembly, evaluation, and discarding of the components of the tests generated a wide variety of waste as discussed below.

From December 1955, when nuclear testing of the HTRE-1 engine commenced, until after 1983, the majority of activity in the waste generated at TAN was shipped from the TAN Hot Shop or hot cells to the RWMC. The experiments and test assemblies were disassembled and examined at these facilities.

During the IET #3 and #4 tests in HTRE-1, because of the rigorous test requirements and the uncertainties with respect to fuel and fuel-clad design, problems developed that led to the melting of the fuel cladding and fuel. The radioactivity produced in the cladding and the fuel contaminated the duct to the stack and the engine internals. These tests were the near-sole source of radioactive waste sent from TAN to the RWMC from December 1955 to February 1957, when testing with the HTRE-2 commenced (Thornton et al. 1962).

During testing of the HTRE-2 inserts, insignificant fuel and fuel-clad melting occurred in the driver core, but fuel, BeO, and fission products were released from the insert configuration to contaminate the reactor and jet engine internals and the duct. This contamination and the discarded insert materials were the sources for the primary waste streams from TAN from March 1957 until the end of the ANP Program in 1961.

Later in the ANP Program, during testing of the HTRE-2 inserts, the hot cells became the dominant source of waste from TAN. During this testing period, the HTRE was brought back to the Hot Shop; the insert was removed from the reactor and taken to the hot cells for examination. After the examination had been completed, the samples and specimens were discarded.

Information about the disposal of the insert material is uncertain based on discussions with personnel previously employed with the ANP Program. A check with personnel at ICPP indicated that no ICPP records existed to show that ceramic fuels had been received or were being stored at ICPP. In addition, the only fuel to be processed at ICPP, other than metallic fuel, was the graphite ROVER (nuclear rocket propulsion program) fuel. To date, no ceramic fuel has been processed at ICPP.

From May 1961 until July 1962, the TAN Hot Shop examined the SL-1 core and reactor vessel (Kunze 1962; GE 1962a). Discarded reactor parts and reactor structural material constituted the majority of the TAN Hot Shop waste stream from May 1961 until August 1962.

Following the first SNAPTRAN test, essentially all of the material (i.e., the environmental tank, the reactor vessel, the internal beryllium reflector), including about 1% of the core fuel, was sent to the RWMC for disposal.

Again, following the second SNAPTRAN test, all of the core structural material, the beryllium reflector, the tank, and a maximum of about 4% of the fuel were eventually sent to the RWMC for disposal. The reclaimed fuel for both tests was sent to ICPP for reprocessing.

During and between the time of the two SNAPTRAN tests, the ML-1 and PM-2A reactor vessel examinations were performed at TAN facilities. These examinations resulted in many metallurgical samples and scrap materials being discarded from the Radiation Measurements Laboratory (RML) and hot cell facilities. Reactor skids, shielding, fixtures, and other parts associated with these systems, not discarded from the RML and hot cells, were discarded from the Hot Shop.

The TAN hot cells generated waste when examining the fuel and other materials received from TMI-2 and LOFT.

Routine operations and maintenance at TAN generated waste such as combustibles used for decontamination and contaminated tools.

General Availability of Information. The waste generated at TAN came from a broad range of sources and was at a peak relatively early (in the early 1960s), when waste recordkeeping was in its early stages. Several programmatic reports provide insights to the activities that generated the waste. These reports furnish supplementary information to the shipping records and RWMIS, which are sketchy during that time period.

In 1958, the AEC Health and Safety Division at the NRTS began to publish an annual report that summarized programmatic activities, including waste disposal at the RWMC. (See the AEC reports provided in the reference list. See also Osloond 1965, 1966, 1967, 1968, 1970, and an undated report.) Data from these reports and associated waste shipping records are considered the best available data for the early years, the time for which there is most question as to the volume of the waste and the contaminants in the waste.

Much information on the characterization of early waste shipments had to be obtained by interviewing personnel who had been involved in packaging the waste.

Reports that allude to waste items considered for disposal were another valuable source of information. Although the reports may not have addressed the waste, they described programs and designs in detail, allowing a defendable identification of the waste items that would have been produced. Because the early waste is most uncertain, many early reports that described the ANP Program were reviewed for the types of material that were used in the IET. These tests were conducted by the U.S. Air Force and were under the purview of an AEC operations office other than the Idaho Operations Office. Therefore, the primary repository for the reports was not at the INEL. Many of the reports that described these tests were not available at the INEL Technical Library until after the INEL Historical Dose Evaluation Study (DOE 1991) had been completed in 1991.

Data-Collection Approach. The general data-collection approach used for TAN was to review programmatic and AEC Health and Safety Division annual reports; conduct interviews with personnel who had worked at TAN during the ANP project, the SL-1 core examination, and the SNAPTRAN tests; review the shipping records; and search the RWMIS database.

The shipping records and RWMIS do not reflect INEL-generated waste before 1960. (Only waste from the RFP is available, and that information is incomplete.) Fortunately, annual totals of radioactivity in INEL-generated waste are available elsewhere (see the AEC reports in the reference list). The activities estimated for 1956, 1957, and 1958 are based on the IET experiments conducted and the amount of fuel damage that occurred during these tests, and they are judged against estimates documented for similar operations that occurred during 1959 and 1960. The IET #3 and #4 tests experienced relatively severe fuel damage, and both of these tests occurred in 1956. The IET #6 through #26 tests were relatively mild with respect to IET #3 and #4 tests fuel damage, but the schedule for the later tests was vigorous with one test closely following another.

As the preceding and following discussions imply, radionuclide distributions were developed from process knowledge and engineering and nuclear physics calculations for each stream. Therefore, no single uniform assumption was made concerning the breakdown of generic radioactivity terms such as MAP and MFP in shipping records.

In an attempt to more accurately characterize these generic radioactivity terms for TAN waste streams, the RSAC-5 computer code (Wenzel 1993) and activation calculations were used as described in this section for 8 of the 10 major waste streams, i.e., TAN-607-1H through TAN-607-4H and

TAN-633-1H through TAN-633-4H. These calculations were based on reactor operating parameters, report information, and discussions with personnel involved with the examinations or operations. The calculations reflect, as accurately as possible, the radionuclides in the respective waste streams. For the minor waste streams and, with one exception, the two remaining major waste streams, TAN-607-5H and TAN-633-5H, the information in Table 2-2 was used for the waste stream characterization. The table was developed based on Plansky and Hoiland (1992), 5-year average radionuclide distributions of all waste shipped in 1987 through 1991 to the RWMC, and consideration of the radionuclides listed in the 10 Code of Federal Regulations (CFR) 61 regulations of the U.S. Nuclear Regulatory Commission (NRC) that apply to commercial disposal facilities for LLW. One exception is that all tritium has been eliminated from the major waste streams because of the high temperature of the early tests, the high volatility of tritium, and the escape directly to the atmosphere. Also, the examination work that generated the waste was conducted principally on structural material that had been out of the reactor for a substantial time; thus, tritium would not have been present in or on structural material.

Description of Waste Streams. The waste generated at TAN was divided into 28 waste streams (see Table 2-3).

The 10 most important waste streams from TAN are discussed in the following paragraphs. For each of these streams, the discussion tells how the stream was generated, the principal contaminants in the stream, the specific information sources reviewed and used, and the assumptions and analysis used to estimate the quantities of contaminants.

TAN-607-1H (HTRE-1 waste)

- **Generation of the waste stream.** This waste stream was generated by the decontamination of the duct to the stack, the reactor, and the jet engine internals and by discard of contaminated and damaged Thermoflex insulating liners after the IET #4 test in HTRE-1.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Cr-51, La-140, Ce-141, Ba-140, Zr-95, Y-91, and Sr-89.

- **Information sources reviewed and used.** The information used to evaluate this waste was taken primarily from Thornton et al. (1962) and from interviews with former ANP Program employees.

Table 2-2. Distributions used for mixed activation products, mixed fission products, unidentified beta-gamma, and unidentified alpha in certain Test Area North waste streams.

	Radionuclides											
Descriptor	C-14	Cm-242	Co-60	Cs-137	H-3	I-129	Pu-241	Sr-90	Tc-99	U-235	U-234	U-238
Unidentified beta-gamma	—	3.2E-11	9.6E-2	0.63	—	7.8E-14	2.8E-5	0.27	1.7E-8	—	—	—
Unidentified alpha	—	5.1E-9	—	—	—	—	4.5E-5	—	—	0.030	0.969	0.001
MAP	2.2E-7	—	1.0	—	—	—	—	—	—	—	—	—
MFP	—	—	—	0.36	0.48	1.2E-13	—	0.16	2.5E-8	—	—	—

Table 2-3. Waste streams originating at Test Area North.

Waste stream number	Description of waste
TAN-603-1H	Backup steam condensate from the TAN Hot Shop into TAN-603 boilers
TAN-606-1H	Unidentified minor waste from the TAN Manufacturing Building during the LOFT era
TAN-607-1H	Decontamination and disposed contaminated parts from the ANP HTRE-1 IET #3, #4 and #6 tests
TAN-607-2H	Contamination and contaminated parts from the ANP HTRE-2 testing (IET #8 through #26 tests)
TAN-607-3H	Activated SL-1 reactor parts contaminated during the SL-1 reactor accident of January 3, 1961, and activated experiment and fuel elements associated with stainless steel
TAN-607-4H	Reactor and auxiliary components from ML-1, PM-2A, and two SNAPTRAN systems
TAN-607-5H	Myriad manufacturing, assembly, health physics, and Hot Shop activities associated with TAN programs
TAN-607-6H	Minor unidentified radioactive waste from the TSF area
TAN-615-1H	U-235-contaminated structures removed during refurbishment of the fuel assembly area of TAN-615
TAN-616-1H	Waste generated in the cleanup of the Liquid Waste Treatment Plant and associated PM-2A secondary evaporator
TAN-620-1H	Minor radioactive waste from the IET Control and Equipment Building
TAN-623-1H	Minor radioactive waste from the sewage pumphouse
TAN-629-1H	Minor radioactive waste from the airplane hanger building during the LOFT and LOFT cleanup eras
TAN-630-1H	Minor unidentified LOFT area waste from TAN-630
TAN-633-1H	RML and hot cell samples and specimens of fuel assemblies from the HTRE-1 IET #3, #4, and #6 tests

Table 2-3. (continued).

Waste stream number	Description of waste
TAN-633-2H	Metallurgical samples and specimens from the HTRE-2 insert tests
TAN-633-3H	Metallurgical samples and specimens examined and discarded from the RML and hot cells resulting from the SL-1 accident of January 3, 1961
TAN-633-4H	Metallurgical samples and specimens from examination of ML-1, PM-2A, and two SNAPTRAN systems
TAN-633-5H	Waste from hot cells abutting TAN-607, with remote-handling equipment for examining radioactive-contaminated material
TAN-636-1H	Minor radioactive waste from the Carpenter and Paint Shop
TAN-640-1H	Rags, plastic, and one radium-beryllium neutron source from the Water Reactor Research Test Facility (WRRTF) Test Building
TAN-641-1H	Minor radioactive waste attributed to the WRRTF Control Building
TAN-645-1H	Minor radioactive waste from the Semiscale Control Building
TAN-647-1H	Low-level radioactive component of the split table reactor from the Radioactive Parts Security Storage Area (RPSSA) Contaminated Storage Building
TAN-650-1H	Minor radioactive waste from the LOFT Containment and Service Building
TAN-711-1H	Minor radioactive waste from the TAN Sewage Treatment Plant
TAN-ANP-3H	Waste from the Low-Power Test Facility
TAN-UNK-1H	Miscellaneous waste from an undetermined building at TAN

- **Assumptions and analysis.** The analysis was based on 30-day-old nichrome-clad activation products, U-235 fuel, and associated fission products generated by the core operated at 10.6 MW for 194 hours (2,065 MW-h), which was the burnup during the IET #4 test. The total assumed radioactivity (from Table 2-4) is 3,000 Ci and applies only to 1956. The distribution of the activity is based on the release of 704 g of fuel and associated fission and clad activation products that would remain after being heated to 1,093°C (2,000°F). The fission product inventory was calculated with the RSAC-5 computer code. The clad activation products were calculated by the methodology provided in Brice and Heath (1960). The fuel release assumed is as documented in DOE (1991) mainly for the IET #3 and #4 tests, and, to a lesser extent the IET #6 test.

TAN-607-2H (HTRE-2 waste)

- **Generation of the waste stream.** This waste stream was generated by the decontamination of the duct to the stack, the reactor, and the jet engine internals and by discard of contaminated and damaged insulation liners and insert shrouds resulting from the testing of the HTRE-2 IET tests.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are La-140, Pr-143, Ce-141, Ba-140, Zr-95, and Sr-89.

- **Information sources reviewed and used.** The following references were reviewed and used as appropriate: Baker (1961); Baker et al. (1959); Blumberg (1960); Evans (1957a, 1957b, 1958a, 1958b, 1959, 1960a, 1960b); Field (1961); Flagella (1962); Foster et al. (1958, 1960); Highberg et al. (1960, 1961); Holtslag (1956); Miller et al. (1960); Pincock (1959, 1960a, 1960b, 1960c, 1960d, 1960e); and Showalter (1959). Interviews were also conducted with former ANP Program employees.

- **Assumptions and analysis.** This waste stream applies to the time period 1957 through 1961. The activity estimates of Table 2-4 are assumed to be valid. The quantities of fuel and associated fission products that leached from the BeO insert matrix at high temperature were estimated as follows. During the HTRE-2 tests, 190 g of U-235 is conservatively estimated to have been released from the reactor core (DOE 1991). The activity for fission products is based on the amount of 30-day decayed fission products that would have been released with 190 g of fuel after being heated to 1,093°C (2,000°F). The fission products were calculated with the RSAC-5 computer code, assuming that the reactor operated at a power level of 14 MW for 100 hours and that the insert generated 7.4% of the total reactor power. Ten percent of the released fuel and associated fission products are ascribed to this waste stream.

TAN-607-3H (Waste from the SL-1 core/vessel examination period)

- **Generation of the waste stream.** This waste stream was generated by the disposal of contaminated materials, such as reactor internals and samples, following the metallurgical, chemical, and radiological examination of the SL-1 accident-generated material. Decontamination of selected materials was also responsible for a small fraction of the waste (Kunze 1962). This waste stream existed only for 1962 and 1963.

Table 2-4. Test Area North contributions to radioactivity in early waste disposed of at the Radioactive Waste Management Complex.

Year	Total onsite radioactivity shipped to the RWMC (Ci)	Percent of radioactivity from TAN (%)	Radioactivity from TAN (Ci)
1952	70	Negligible	Negligible
1953	800	Negligible	Negligible
1954	1,500	Negligible	Negligible
1955	1,500	Negligible	Negligible
1956	10,000	30[a]	3,000
1957	15,000	13[a]	2,000
1958	10,000	20[a]	2,000
1959	23,704	8.3[b]	1,915
1960	9,246	19.4[b]	1,710
1961	155,039	1.36[b]	2,110[c]
1962	118,177	14.3[b]	16,000
1963	253,565	Negligible	<0.1
1964	145,485	Negligible	Negligible

a. Assumed value. The percentage of total onsite radioactivity in the waste from TAN was assumed to be as shown for 1956 through 1958 based on general knowledge of the extent of contamination produced in the TAN projects for that time period.

b. Percentage of onsite radioactivity from TAN was calculated based on known activity from TAN.

c. Based on the sum of curie values disposed of from TAN on the shipping records.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Ce-144, Pm-147, Cs-137, Sr-90, Co-60, and Ru-106.

- **Information sources reviewed and used.** The following sources were reviewed and used as appropriate: Kunze (1962); General Electric Company (1961a, 1961b, 1961c, 1961d, 1962a, and 1962b); RWMIS; waste shipping records; interviews with former ANP Program employees; and TAN Hot Shop, RML, and fuel transfer logs.

- **Assumptions and analysis.** The principal contaminants were activation products produced in the vessel internal structural materials and fission products produced by a 931 MW-d operation, followed by a shutdown of 7 days and a subsequent criticality event of 133 MW-s. All of the activity before shipment was assumed to be decayed by an average of 450 days post-criticality. (The reactor vessel was moved to TAN on November 30, 1961, about 332 days following the accident.)

  The fission product inventory of the core was calculated with the RSAC-5 computer code for the documented steady-state operation in the 93% enriched core, the 7-day decay, and the 133 MW-s criticality event. Activation product activities are based on sample analysis results provided in Kunze (1962) and GE (1961b, 1961c, 1961d, 1962a, and 1962b). For the activated hardware that comprised the majority of the waste activity, type 304 stainless steel with high burnup and 1-year decay was assumed to determine the radionuclide distribution.

TAN-607-4H (Waste from reactor and auxiliary components of ML-1, PM-2A, and the two SNAPTRAN systems)

- **Generation of the waste stream.** This waste stream includes the reactor components generated during the ML-1 and PM-2A reactor vessel examinations and during the two SNAPTRAN tests that were conducted at TAN during the period 1964 through 1966.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Ce-144, Pm-147, Cs-137, Sr-90, Co-60, Ru-106, Ba-140, and La-140.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this stream are beryllium and lead.

- **Information sources reviewed and used.** The following sources were reviewed and used as appropriate: Cordes et al. (1965, 1967); Fletcher (1964, 1965); Mousseau et al. (1967); Murphy et al. (1966); radioactive waste manifests; and interviews with personnel involved with the SNAPTRAN tests and the ML-1 and PM-2A reactor vessel examinations.

- **Assumptions and analysis.** A review of the radioactive waste manifests shows the majority of the waste from the Hot Shop to be routine hot waste and that activities were aimed at preparing the facility for the ML-1 and PM-2A examinations. The radionuclide distribution is assumed to be from decayed SL-1 fission products, calculated by the RSAC-5 computer code, and decayed to the appropriate time for shipment to the RWMC.

The mass of the beryllium contained in the SNAPTRAN reactor internal and external reflectors was calculated based on drawings because the quantity is not provided in the reports cited. The total radioactive waste for the 3-year period for this waste stream amounted to only 12.75 Ci; the majority of radioactive waste from TAN for this period is attributed to a companion waste stream, TAN-633-4H.

TAN-607-6H (Miscellaneous Hot Shop waste)

- **Generation of the waste stream.** This waste stream, which consisted of miscellaneous LLW generated from 1967 to 1983 not included in the other five TAN-607 streams, resulted from contaminated and activated pieces of stainless steel and decontamination materials from operations in the TAN Hot Shop.

- **Principal radiological contaminants.** The principal radiological contaminants in this stream are Co-60, Cs-137, and Sr-90.

- **Information sources reviewed and used.** Information concerning this stream was taken from RWMIS.

- **Assumptions and analysis.** The activities of the radiological contaminants in this stream were taken from RWMIS.

TAN-633-1H (HTRE-1 metallurgical samples and hot cell waste)

- **Generation of the waste stream.** This waste was generated by the need to dispose of metallurgical samples and other materials associated with the HTRE-1 IET #3, #4, and #6 tests.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Cr-51, La-140, Ce-141, Ba-140, Zr-95, Y-91, and Sr-89.

- **Information sources reviewed and used.** The information used to evaluate this waste was taken primarily from Thornton et al. (1962).

- **Assumptions and analysis.** The analysis of the metallurgical samples was based on the same assumptions used for the test hardware from which the samples were fabricated. These assumptions were described for waste stream TAN-607-1H.

TAN-633-2H (Waste from the HTRE-2 IET tests)

- **Generation of the waste stream.** This waste stream was generated by the need to dispose of metallurgical samples and other materials associated with the HTRE-2 IET tests.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are La-140, Pr-143, Ce-141, Ba-140, Zr-95, and Sr-89.

- **Information sources reviewed and used.** The following references were reviewed and used as appropriate: Baker (1961); Baker et al. (1959); Blumberg (1960); Evans (1957a, 1957b, 1958a, 1958b, 1959, 1960a, 1960b); Field (1961); Flagella (1962); Foster et al. (1958, 1960); Highberg et al. (1960, 1961); Holtslag (1956); Miller et al. (1960); Pincock (1959, 1960a, 1960b, 1960c, 1960d, 1960e); and Showalter (1959).

- **Assumptions and analysis.** This waste stream of metallurgical samples applies to the time period 1957 through 1961 and assumes that the activity estimates of Table 2-4 are valid. The quantities of fuel and associated fission products that leached from the BeO insert matrix at high temperature were estimated as described for waste stream TAN-607-2H.

TAN-633-3H (Waste from the SL-1 core/vessel examination period; 90% of the released fuel and associated fission products are ascribed to this waste stream)

- **Generation of the waste stream.** This waste stream was generated by the need to dispose of metallurgical samples and other materials associated with the SL-1 core and vessel examination, and it includes the years 1962 and 1963.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Ce-144, Pm-147, Cs-137, Sr-90, Co-60, and Ru-106.

- **Information sources reviewed and used.** The following sources were reviewed and used as appropriate: Kunze (1962); GE (1961a, 1961b, 1961c, 1961d, 1962a, and 1962b); RWMIS; and waste shipping records.

- **Assumptions and analysis.** The metallurgical samples and resulting scrap were assumed to be contaminated with activation products produced in the vessel internal structural materials and fission products produced by the reactor operation as described for waste stream TAN-607-3H.

TAN-633-4H (Waste from the SNAPTRAN tests and ML-1 and PM-2A vessel examinations)

- **Generation of the waste stream.** This waste stream was generated by the need to dispose of waste and metallurgical samples from the ML-1 and PM-2A vessel examinations and the SNAPTRAN tests. Because available documentation does not separate these operations in time, this stream includes the years 1964 through 1966.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Ce-144, Pm-147, Cs-137, Sr-90, Co-60, Ru-106, Ba-140, and La-140.

- **Information sources reviewed and used.** The following sources were reviewed and used as appropriate: Cordes et al. (1965, 1967); Fletcher (1964, 1965); Mousseau et al. (1967); Murphy et al. (1966); radioactive waste manifests; and interviews with personnel involved with the SNAPTRAN tests and the ML-1 and PM-2A reactor vessel examinations.

- **Assumptions and analysis.** An analysis of the waste described on the radioactive waste manifest forms showed the percentage waste attributed to ICPP Waste Calcining Facility off-gas filters and hot cell filters, to the amount of fuel materials disposed of, and to the amount of activated stainless steel disposed of. The assumptions for radionuclide loading on the filters, based on information from ICPP personnel, were that (a) there are equal percentages of Cs-137 and Sr-90 and (b) 1% of the total gamma activity is Pu-238. Therefore, to use the year 1964, for example, when 304 Ci was attributed to the disposal of these filters, the associated activity would be 304 Ci of Cs-137, 304 Ci of Sr-90, and 3 Ci of Pu-238 because neither the curies of Sr-90 nor Pu-238 would have registered on the gamma activity reading made by the TAN health physics technician for disposal purposes. The U-235 fuel material documented for disposal was assumed to be 93% enriched, the normal enrichment for this time period. The activity of the irradiated stainless steel was assumed to be for stainless steel type 304 with high burnup conditions and a 1-year decay, as described in DOE (1992).

TAN-633-5H (Miscellaneous hot cell waste)

- **Generation of the waste stream.** This waste stream, which consists of miscellaneous LLW generated from 1967 to 1983 not included in the other five TAN-633 streams, resulted from contaminated and activated pieces of stainless steel and decontamination materials from operations in the TAN Hot Shop.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Co-60, Cs-137, and Sr-90.

- **Information sources reviewed and used.** Information concerning this stream was taken from RWMIS.

- **Assumptions and analysis.** The activities of the radiological contaminants in this stream were taken from RWMIS.

2.4.2 Test Reactor Area

The Generator. TRA is located approximately 8 km (5 mi) north of CFA and approximately 3.2 km (2 mi) west of ICPP at the INEL (see Figure 2-1). The major facilities at TRA are the test reactors: Materials Test Reactor (MTR), operating from 1952 to 1970; Engineering Test Reactor (ETR), operating from 1957 to 1981; and Advanced Test Reactor (ATR), operating from 1969 to the present. In addition to the test reactors and their support facilities, the following facilities and laboratories have been or are currently operating at TRA:

- TRA hot cells (1952 to present)

- Radiation Measurements Laboratory (RML) (1952 to present)

- Nuclear physics laboratories (1953 to present)

- Radiochemistry laboratories (1952 to present)

- Advanced Test Reactor Critical (ATRC) (1968 to present)
- Engineering Test Reactor Critical (ETRC) (1957 through 1980)
- Reactivity Measurements Facility (RMF) (1956 through 1960)
- Advanced Reactivity Measurement Facility (ARMF) (1960 through 1992)
- Gamma facility
- Metallurgical laboratories
- Hydraulics test facility
- Nuclear materials inspection storage facility
- Maintenance shops.

All of the TRA reactors have used highly enriched uranium (i.e., 93% U-235) as their nuclear fuel. The fuel is contained in fuel element assemblies that are composed of multiple fuel plates. The central core of each fuel plate contains a matrix of uranium and aluminum called UAl_x, and the core is covered by an outer layer of pure aluminum. Reactor cores are cooled and neutron-moderated with water. The MTR, ETR, ATR, ETRC, and ATRC have beryllium reflectors surrounding or adjacent to the reactor cores, while the RMF and ARMF have water reflectors surrounding the reactor cores. The beryllium was replaced every 7 to 10 years; therefore, a large quantity of beryllium has been disposed of at the RWMC.

Irradiated fuels from the TRA reactors were stored in canals near the reactors for a cooling period and then shipped to ICPP for processing. The gamma facility and each reactor or critical facility had a canal to store irradiated and unirradiated fuel and irradiated experiment assemblies.

The major role of a test reactor is to test the physical, chemical, and nuclear properties of materials during and after exposure to highly intense neutron/gamma fields. Experiments are placed in the reactor core or in the reflector adjacent to the reactor core. The size of the experiments varies from a small irradiation capsule to a major irradiation loop. The standard loop experiment consists of a pressurized water piping system with its own cleanup system, and it is designed to provide the controlled physical and chemical conditions for the test region. Typical conditions that are monitored and controlled include the temperature, pressure, and pH of the experiment coolant. The major sponsors of the test reactors have been and continue to be the Bettis Atomic Power Laboratory and the Knolls Atomic Power Laboratory, funded by the Naval Reactors Program (NRP) of DOE and its predecessor agencies. Experiments from these users are designed or specified by the sponsor. After completing the irradiation, the test internals are generally transferred to the sponsor's facilities for disassembly and examination or to the TRA hot cells.

The MTR (TRA-603), the first test reactor at TRA, began full-power operation in 1952. The loading of the reactor core contained approximately 5 kg of U-235. It operated for most of its life at a power level of 40 MW (thermal power).

The primary goal of the MTR tests was to support the development of fuels for the nuclear propulsion systems on naval vessels. Much of the testing in the MTR dealt with developing zircaloy-clad fuels for pressurized water reactor systems. In addition to the naval experiments, major experiments were carried out for the ANP Program, the space nuclear reactor project, and the development of advanced aluminum-clad nuclear fuel for research and test reactors. The MTR was also used to produce radioactive isotopes, primarily for nuclear research.

Physics experiments in the MTR were generally devoted to measuring neutron cross-sections and nuclear decay properties of radioactive materials. In the early 1960s, the neutron cross-section measurements were extended to target materials such as the radionuclides of protactinium, plutonium, curium, and promethium. To support these measurements, the alpha wing (TRA-661) of the MTR was constructed. In this wing, samples irradiated in the MTR were radiochemically processed to produce target materials for cross-section measurements.

The MTR operated until 1970, when it was placed on inactive status. Beginning in 1975, the emergency core-cooling working reservoir, an elevated water tank, and primary and secondary coolant systems were dismantled. The reactor fuel and beryllium reflector were removed, and the beryllium was sent to the RWMC. The major loop experiments have all been removed and transferred to either the ATR, ETR, or RWMC. With the exception of the fuel and beryllium, the reactor core internals remain inside the reactor vessel.

To provide higher neutron fluxes and a better ability to control the experimental conditions, the ETR (TRA-642) was constructed; it began full-power operation in 1957. The ETR used the same type of fuel as the MTR. The operating power level was 175 MW, and the core loading was approximately 30 kg of U-235.

The ETR operated as a test reactor until 1973, at which time the naval test loops were transferred to the ATR. The facility was inactive from 1973 to 1975. In 1975, the ETR was reconfigured to support the fast reactor development program under the sponsorship of Argonne National Laboratory. The name given to this experiment was the Sodium Loop Safety Facility (SLSF). For these tests, the ETR operated on a very limited basis. There would be a short period of operation to precondition the fuel in the test section, then the experiment assembly would be subjected to simulated accident scenarios while in the ETR core. After each test, the internal test assemblies would be removed from the ETR and shipped to ANL-W for examination. The containment and outer portions of the SLSF assembly would remain in the ETR core and would be made ready to accept the next experiment assembly from ANL-W. This experiment used liquid sodium; however, after the SLSF test series was completed, all of the sodium was returned to ANL-W. No sodium was sent from TRA to the RWMC. The SLSF experiments were concluded in 1981, and the ETR was placed on inactive status from 1981 to 1982. In 1982, the ETR was decontaminated, the primary and secondary cooling systems were dismantled, and the facility was placed on permanent inactive status.

The ATR (TRA-670) was the last of the three test reactors built at TRA. It began full-power operation in 1969. Unlike the rectangular MTR and ETR cores, the ATR core is in the shape of a four-leaf clover. There are nine major regions for experiments. The power for each region can be tailored to meet the experimenters' requirements. The maximum power level of the ATR is 250 MW; however, it typically operates at a power level of about 125 MW. The core loading for the

ATR is approximately 40 kg of U-235. It was necessary to change the beryllium reflector and core internals every 7 to 10 years.

From 1969 to 1992, the ATR was operated almost exclusively for the NRP. Since 1992, there has been some diversity in the experiments conducted in the ATR; however, the NRP still remains the primary user of the facility. In addition to NRP experiments, isotope production experiments and experiments for the New Production Reactor Program have been conducted.

To support reactor safety assurance and experiment needs, the ETR and ATR had critical assemblies (the ETRC and ATRC, respectively), which were nuclear mockups of the reactors. The major function of these critical assemblies was to measure reactor criticality and the effect that experiments would have on criticality. These reactors operated at low power levels (less than 1 kW). At these power levels, the fuel and core structural parts can be handled without using remote-handling equipment or shielding. In 1981, the ETRC was dismantled; all of the fuel, the core structure, and the beryllium reflector have been disposed of. The ATRC is still operating in support of the ATR.

The RMF and its successor, the ARMF, were designed to be critical assemblies for precisely measuring the neutron cross-sections of materials slated for use in or produced by reactors. The RMF was located in the canal of the MTR and used unirradiated MTR fuel elements. It typically operated at less than 100 W. The ARMF replaced the RMF and was located in a separate building (TRA-660) east of the MTR building. The ARMF contains two critical assemblies, ARMF-I and ARMF-II, which share a common canal. In 1969, ARMF-II was reconfigured to support the fast reactor development program. A block of U-238 was placed in the center of the core. After this conversion, the ARMF-II was renamed the Coupled Fast Reactivity Measurement Facility. In 1992, these reactors were placed on temporary inactive status.

The TRA hot cells have been an integral part of test reactor support operations since the beginning of operations at the MTR. They are used for disassembly and examination of irradiated samples and experiment assemblies from the test reactors. Until the Expended Core Facility (ECF) at NRF was constructed, the TRA hot cells were the primary handling facility for the naval experiment assemblies irradiated in the MTR. Much of the experiment waste sent to the RWMC was generated at the hot cells. After the ECF was operational, almost all irradiated naval reactor experiment assemblies were processed through ECF. However, the TRA hot cells still support the test reactor programs. In the 1970s and early 1980s, the TRA hot cells processed severe damage fuel experiments conducted at PBF and analyzed small fuel samples from the damaged TMI-2 reactor and the H. B. Robinson commercial power plant.

The other operations at TRA will not be described because they are very minor generators of waste sent to the RWMC.

Generation of the Waste. Most of the waste generated at TRA is associated with the operations of the test reactors and the examination of irradiated experiment assemblies in the TRA hot cells. Most of the radioactive waste generated at TRA contains radioactive fission products produced in the nuclear fuel and radionuclides produced by neutron activation. The nuclear fuel-produced radioactivity is typically classified as MFP; however, some activation products are associated with certain fuels. Neutron activation products are typically classified as MAP. The actual distribution of

specific nuclides in either MFP or MAP depends on the reactor fuel and the process that generated the waste.

The irradiated fuel is normally sent as intact assemblies to ICPP for processing; however, in some instances, fuel elements are disassembled in the TRA hot cells. Because most of the reactor fuel is processed at ICPP, the bulk of the fission product activity ends up in ICPP waste. Only a minor component of that activity is left at TRA. This component is the result of fission products leaking through the reactor fuel cladding into the reactor coolant. The fission products then can potentially contaminate all items that come in contact with the coolant. This includes materials inside the reactor vessel and pipes, pumps, and cleanup systems associated with the primary coolant.

In addition to fuel leakage, there can also be leakage of radioactivity from the fueled experiments. This primarily contaminates the experiment coolant and cleanup system, and it secondarily contaminates the main reactor coolant. When these experiments are disassembled in the TRA hot cells, the irradiated components and associated handling equipment and materials are contaminated and become waste.

The filters in the reactor and hot cell ventilation systems also contain some of the fission products produced in the reactor fuel and fueled experiments. Although the reactors are water-cooled, there have been experiments in which the coolant has been gaseous. In those cases, the filters from cleanup systems of those experiments were contaminated and eventually sent to the RWMC. For example, a gaseous coolant experiment was performed for the ANP Program in the MTR during the 1950s.

Activation products are produced when neutrons are captured or otherwise interact to produce radionuclides. Neutron interactions can occur in the reactor fuel, and the radionuclides are carried along with the fission products. Neutrons can also interact with reactor and experiment structural components, resulting in radionuclides becoming fixed contamination in those components and also through corrosion in the reactor or experiment coolant. In the coolant system, the radionuclides can potentially contaminate the same items as the fission products. Therefore, for radioactive waste generated by test reactor operations and support activities, there will be a mixture of fission products and activation products.

In addition to fission products and activation products, TRU radionuclides are produced in a reactor. These radionuclides are produced by multiple neutron capture events, combined with beta and alpha decay. In the early days of the MTR, several experiments were designed to generate these nuclides for research purposes. However, that effort was very small in terms of waste generation and was virtually completed by the mid-1950s. From that point on, the test reactors were used to produce minor amounts of TRU radionuclides, generally in the microcurie range. Most TRU radionuclides not bound in reactor fuel were brought to the INEL from offsite producers.

The hot cells are the second largest generator of waste at TRA. In addition to experiments in the test reactors, the TRA hot cells have been used to process experiments performed outside TRA. These include the severe fuel damage experiments performed at PBF and fuel samples from the damaged TMI-2 reactor. The PBF and TMI fuel contains low-enriched uranium (approximately 4% U-235 by mass). The radionuclide distributions in these fuels are different from those in the test

reactor fuels. In addition, the activation products because of the zircaloy cladding are different from activation products generated by test reactors.

Almost all items removed from the hot cells are considered to be radioactive. If there is no further need for these items, they are classified as radioactive waste.

The critical facilities (i.e., ATRC, ETRC, and ARMF) contribute small amounts of radioactive waste, most of which is carried into the facilities on samples and experiments from the test reactors or from non-TRA facilities. In most cases, the mix between fission products and activation products is about the same as that found for the test reactors.

The radiochemistry and physics laboratories at TRA handle small quantities of radioactive materials as part of their research, typically microcuries to millicuries. The hot cell and the californium cell in the alpha wing (TRA-661) are possible exceptions. Originally, the alpha-wing hot cell was constructed to fabricate radioactive targets for the MTR cross-section measurements program. When that program ceased, the glove boxes and hot cell liners were sent to the RWMC. Since then, the radiochemistry programs have used the alpha-wing hot cell to separate transuranics and other research efforts. The californium cell contains microgram amounts of Cf-252 used to produce nanocurie amounts of fission products for nuclear decay measurements. The alpha-wing solid waste has higher concentrations of alpha-emitters from the decay of TRU nuclides. The remainder of the radiochemistry and physics laboratories generate waste similar in content to reactor plant waste.

The gamma facility was used to expose food items and other materials to high doses of gamma radiation from intact spent fuel elements. The fuel elements were then shipped to ICPP for processing. The gamma facility was operating in the 1950s and early 1960s. During that period, the reports about TRA waste shipped to the RWMC did not specify whether the waste was generated at the gamma facility or some other facility at TRA. Any waste generated at the gamma facility would not differ significantly in radionuclide distribution from normal plant waste or canal waste. Also, the amount of waste (in curies) generated at the gamma facility was minor compared with that generated by the test reactors.

Radioactive liquid waste from TRA was disposed of in the TRA waste retention basins (if low to moderate activity) or sent to ICPP for processing (if moderate to high activity).

The test reactors were the major generators of nonradiological contaminants in TRA waste sent to the RWMC. The primary contaminant is beryllium. This waste is generated when a reactor reflector is replaced.

Cadmium was used frequently as a neutron shield. Some of this material was sent to the RWMC from TRA.

The following are examples of waste streams sent to the RWMC from TRA.

- Ion-exchange resins used in the reactor coolant cleanup systems.

- Irradiated fuel element end boxes that were cut off the fuel plates in the hot cells. The end boxes may contain some fuel, but they generally contain only activation products.

- Core and experiment loop components constructed of aluminum, stainless steel, or zircaloy. They generally contain activation products.

- Contaminated glassware from radiochemistry and physics laboratories. They can contain fission products, activation products, or alpha-emitters.

- Contaminated vermiculite. It was used to clean up liquid spills and can potentially contain fission products, activation products, or alpha-emitters.

- Contaminated air filters. They were used to remove airborne contaminants in fume hoods, glove boxes, and ventilation systems.

- Contaminated rags and floor sweepings.

- Contaminated concrete, bricks, and wood.

- Uranium powder. This may be irradiated or unirradiated. The unirradiated uranium may contain sufficient activity from U-234 to classify it as radioactive.

- Irradiated beryllium from the reactor reflector changeouts.

- Contaminated or activated lead no longer useful for shielding. The major activation products are generated in antimony, which is present in most commercially available lead.

General Availability of Information.

Period 1952 through 1959—For this early period, the data source believed to be most reliable is the letter file of the health physics supervisor, John F. Sommers, during the period 1953 to 1959 (approximately 110 letter reports). Two types of letters appear in this file concerning waste sent to the RWMC: monthly progress reports and radioactive waste disposal reports. The monthly progress reports contain the number of shipments from TRA to the RWMC during the month, but they are of little value. The radioactive waste disposal reports list the radioactivity shipped during the month. However, for most years, there are missing months. For 1952, there are no entries; 1953 has 4 entries; 1954 has 11 entries; 1955 has 12 entries; 1956 has 10 entries; and there are no entries for 1957 or later years.

For the years when monthly records were missing from the letter file of the health physics supervisor, yearly amounts were established by averaging the monthly radioactivity for the months data were available and multiplying by 12. For 1952, no data were available, so the amount in 1952 was estimated as one-half of the 1953 amount. The rationale for this approach is that the amount doubled from 1953 to 1954, and doubled again from 1954 to 1955.

Estimates of the activity in TRA waste for 1957, 1958, and 1959 are from the annual reports of the Health and Safety Division for these years (see AEC reports in the reference list and Cassidy 1982).

Period 1960 through 1969—The data for this time period were obtained from the AEC Health and Safety Division annual reports (see AEC reports in the reference list); Osloond (1965, 1966, 1967, 1968); shipping records; and RWMIS. An assessment of the SDA for the period 1952 through 1970 also produced data (Vigil 1990; Plansky and Hoiland 1992).

Period 1970 through 1979—Information for this time period is available in the Aerojet waste management plans and revisions (Hickman 1972, 1974) and RWMIS. The information, for the most part, is identical in the various sources. An additional source for 1975 is ERDA (1977). The years 1975 and 1978 show discrepancies in the values. In the case of an unresolved discrepancy, the higher value was used.

Period 1980 through 1983—For this period, the RWMIS values and those from other sources [Cassidy (1982) and the radioactive waste management information reports for 1979 through 1982 (see DOE reports in the reference list)] agree reasonably well. Another survey of the inventory was completed in 1991 (Barnard et al. 1991).

Several other information sources were reviewed for the task, but they did not yield definitive information about the waste. The following sources did give insight, however, as to what operational activities were going on and when: Adams (1985); Aerojet Nuclear (1970, 1971, 1972, 1973, 1975a, 1975b, 1976); Akers et al. (1993); Allied Chemical Corporation (1971); Brenton (1956); Bright (1958, 1959a, 1959b); Browder (1985); Chamberlain (1971); Clements (1981); Coates (1982); Commander (1971); EG&G Idaho (1984); Frank (1984); GE (1985); Gruen (1982a, 1982b); Hanson (1952); INC (1969a, 1969b, 1970a, 1970b, 1970c, 1971a, 1971b); Jones and Kern (1958); McMurry (1954); Nelson (1959); Norberg (1959); PPCo (1961a, 1961b, 1966); Price (1958); Simpson et al. (1982); Stroschein (1967); Watanabe (1958); Witt (1957); and the MTR cycle reports for Cycles 16 through 200, from June 1959 through December 1963.

The general trend of the disposed radioactivity follows the initiation and termination of facilities at TRA. After MTR startup, waste disposal increased steadily with time until the startup of the ETR. After startup of the ETR, waste disposal increased again. Waste disposal increased shortly before startup of the ATR, as experiments were removed from the MTR and ETR and transferred to the ATR. After shutdown of the MTR, waste disposal decreased until D&D operations at the MTR were initiated, and then it rose again (Kaiser 1984; Smith 1985). After the cleanup of some of the MTR facilities, the waste amounts decreased because little D&D was performed on the ETR facilities.

Data-Collection Approach. The data sources used for TRA waste were (a) monthly and annual reports and letters, (b) topical reports, (c) shipping records, and (d) RWMIS entries. For simplicity, all of these sources are referred to in this discussion as generic reports. In addition, nuclear physics considerations and calculations were used to obtain the radionuclide distributions in many cases.

Reports and shipping records provide varying degrees of completeness in specifying radionuclide distributions. The following information describes how the available records and reports were

combined with nuclear physics evaluations to project a reasonably complete distribution of radionuclides having the appropriate total amount of radioactivity.

Table 2-5 is the master list of radionuclides considered in calculating the nuclide-by-nuclide activity breakdown of the waste generated at TRA. This list is a composite based on (a) a performance assessment of dose at the RWMC performed in 1993, (b) the reporting requirements imposed by the NRC on waste from operating power reactors (10 CFR 61), and (c) the expected importance of the radionuclide in TRA waste. Based on an activity build-up calculation using the ORIGEN2 computer code (Graff 1980; Schnitzler 1994) for a typical ATR fuel element irradiation history, the activity for any TRU radionuclide with an atomic number or mass greater than that of Cm-244 is too weak to be reportable and is not included.

Radioactive waste generated at TRA has been reported as individual nuclides, MFP, MAP, unidentified beta-gamma, or unidentified alpha. Most waste streams or waste generation processes at TRA contain all types of activity; however, the relative mix differs. Because there are different mixes, it was decided that the waste should be categorized according to the generator mode or generic content, rather than by activity. Based on a review of commercial power plant waste reports (e.g., EPRI 1987) and other sources, six general categories of waste were identified by analogy for TRA:

1. Unirradiated fuel
2. Irradiated fuel
3. Dry radioactive waste not otherwise specified
4. Reactor coolant resins
5. Sludge
6. Unidentified alpha.

Tables 2-6 through 2-11 list the radionuclides and the activity scaling factors for each waste category. Scaling factors are fractions or percentages representing the activity of one radionuclide relative to the activity of another radionuclide or to the total activity of a group of radionuclides. (Section 5 provides a detailed discussion of radioactivity distributions and scaling factors.) INEL data for the scaling factors of difficult-to-measure radionuclides in TRA waste are limited. Therefore, many of the scaling factors for these radionuclides were taken from data gathered on commercial nuclear power reactors (EPRI 1987). There are limitations in applying those data to waste from INEL test reactors, but these data are the most applicable available data.

The scaling factors are based on fractional activities consistent with the assumption that measuring total activity using the G-M method would include only gamma activity. (Section 5 discusses the detailed G-M method and its limitations.) The approach followed to generate tables that used more than one data source is described in Harker and Akers (1994) and in Harker (1995a).

Use of Standard Waste Categories for Various Situations—For the years 1952 to 1960, the information is given in monthly and annual reports in terms of total radioactivity, and it

Table 2-5. Master list of radionuclides evaluated for waste from the Test Reactor Area.

Nuclide	Half-life[a] (years)	Decay mode[b]	Fission product	Activation product
Am-241	433	α	—	X
C-14	5.7×10^3	β	—	X
Ce-144	0.78	$\beta+\gamma$	X	—
Co-60	5.3	$\beta+\gamma$	—	X
Cm-242	0.45	α	—	X
Cm-244	18.1	α	—	X
Cs-137	30.2	$\beta+\gamma$	X	—
Fe-55	2.73	β	—	X
Eu-152	13.5	$\beta+\gamma$	X	—
Eu-154	8.6	$\beta+\gamma$	X	—
Eu-155	4.7	$\beta+\gamma$	X	—
H-3	12.3	β	X	X
I-129	1.6×10^7	$\beta+\gamma$	X	—
Nb-94	2.0×10^4	β	—	X
Ni-59	7.6×10^4	β	—	X
Ni-63	100	β	—	X
Np-237	2.1×10^6	α	—	X
Pu-238	87.7	α	—	X
Pu-239	2.4×10^4	α	—	X
Pu-240	6.6×10^3	α, sf	—	X

Table 2-5. (continued).

Nuclide	Half-life[a] (years)	Decay mode[b]	Fission product	Activation product
Pu-241	14.4	β	—	X
Ra-226	1.6×10^3	α	—	—
Sb-125	2.8	$\beta+\gamma$	X	X
Sr-90	29	β	X	—
Tc-99	2.1×10^5	β	X	—
U-232	70	α	—	—
U-233	1.6×10^5	α	—	—
U-234	2.5×10^5	α	—	—
U-235	7.0×10^8	α	—	—
U-236	2.3×10^7	α	—	—
U-238	4.5×10^9	α	—	—

a. Half-lives taken from GE (1989).

b. α = Decays by alpha emission
β = Decays by beta emission
$\beta+\gamma$ = Decays by beta emission plus gamma transitions
α, sf = Decays by alpha emission and spontaneous fission.

Table 2-6. Nuclides and activity scaling factors for highly enriched uranium unirradiated fuels from the Test Reactor Area.[a]

Nuclide	Activity scaling factor[b]
U-234	0.95
U-235	0.05
U-238	0.00

a. Applies to MTR, ETR, and ATR fuels.

b. Scaling factors are based on highly enriched uranium (93% U-235 by mass).

Table 2-7. Nuclides and activity scaling factors for irradiated fuels from the Test Reactor Area.[a]

Nuclide	Activity scaling factor[b]
H-3	1.9×10^{-3}
Sr-90	4.3×10^{-1}
Tc-99	5.5×10^{-5}
Sb-125	2.5×10^{-2}
I-129	1.0×10^{-7}
Cs-137	4.5×10^{-1}
Eu-152	1.6×10^{-6}
Eu-154	3.4×10^{-2}
Eu-155	2.1×10^{-2}
U-234	4.6×10^{-6}
U-235	1.0×10^{-7}
U-238	1.8×10^{-6}
Np-237	2.8×10^{-6}
Pu-238	1.2×10^{-2}
Pu-239	5.0×10^{-5}
Pu-240	3.1×10^{-5}
Pu-241	2.0×10^{-2}
Pu-242	3.1×10^{-7}
Am-241	3.4×10^{-5}
Am-243	4.0×10^{-6}
Cm-242	2.0×10^{-4}
Cm-244	5.5×10^{-4}

a. Applies to MTR, ETR, and ATR fuel unless otherwise specified on the data source. This applies to all irradiated fuels discarded from the TRA hot cells.

b. Activity scaling factors are based on an ORIGEN2 calculation for one ATR fuel element irradiated for 85 days at 8 MW per element and allowed to decay for 1 year after irradiation (Graff 1980; Schnitzler 1994).

Table 2-8. Nuclides and activity scaling factors for dry radioactive waste from the Test Reactor Area.

Nuclide	Activity scaling factor[a]	Data source
H-3[b]	8.2×10^{-2}	EPRI (1987)[c]
C-14	1.1×10^{-3}	EPRI (1987)[c]
Fe-55	1.9	EPRI (1987)[c]
Co-60	6.7×10^{-1}	EPRI (1987)[c]
Ni-59	5.7×10^{-4}	Evans et al. (1984)[d]
Ni-63	3.2×10^{-1}	EPRI (1987)[c]
Sr-90	9.2×10^{-4}	EPRI (1987)[c]
Tc-99	1.8×10^{-4}	EPRI (1987)[c]
I-129	4.4×10^{-8}	Harker (1995b)[e]
Cs-137	2.0×10^{-1}	EPRI (1987)[c]
Ce-144	4.7×10^{-3}	EPRI (1987)[c]
Eu-154	2.9×10^{-6}	Evans et al. (1984)[d]
Eu-155	9.4×10^{-3}	Graff (1980) and Schnitzler (1994)[f]
U-234	2.1×10^{-6}	Graff (1980) and Schnitzler (1994)[f]
U-235	4.5×10^{-8}	Graff (1980) and Schnitzler (1994)[f]
U-236	8.0×10^{-7}	Graff (1980) and Schnitzler (1994)[f]
Np-237	1.2×10^{-6}	Graff (1980) and Schnitzler (1994)[f]
Pu-238	5.4×10^{-5}	EPRI (1987)[c]
Pu-239	5.4×10^{-5}	EPRI (1987)[c]
Pu-240	5.6×10^{-6}	Graff (1980) and Schnitzler (1994)[f]
Pu-241	5.9×10^{-3}	EPRI (1987)[c]

Table 2-8. (continued).

Nuclide	Activity scaling factor[a]	Data source
Am-241	2.7×10^{-5}	EPRI (1987)[c]
Cm-242	2.7×10^{-5}	EPRI (1987)[c]
Cm-244	2.5×10^{-5}	EPRI (1987)[c]

a. It was assumed that the measured activity was determined by a predominantly gamma-sensitive device (e.g., G-M counter, NaI scintillation detector). As such, only gamma activity was reported. However, there were cases where the gamma activity was increased to account for the beta-emitters. This correction was not universally applied and, in many cases, not even noted. To be conservative, it was assumed that the reported activity (MAP, MFP, and unidentified beta-gama) includes only gamma activity. The scaling factors listed in this table have taken the beta activity into account. Therefore, the sum of the scaling factors is a number greater than unity. The difference between the sum and unity is the relative beta activity. See Harker (1995a) for details on how the scaling factors were derived.

b. There is a question as to whether tritium is present at the fraction indicated in this table for all dry waste. Tritium is present in dry waste that has direct contact with the reactor coolant and, in some cases, where there has been secondary contact. The tritium scaling factor listed in this table represents a history of experience with pressurized water reactors and should give numbers that are valid on the average. However, in those cases where there was evidence that tritium was not present or was present in much lower concentrations, the scaling factor for tritium in the table was not used. A note to this effect was placed with that data entry.

c. Dry active waste generated by all commercial pressurized water reactors in the United States.

d. Activation products in 304 stainless steel.

e. The factor was based on the ratio of I-131 activity to Cs-137 activity in ATR primary coolant water and on ratios of I-129, I-131, and Cs-137 activities calculated with ORIGEN2.

f. ORIGEN2 calculation based on irradiating an ATR fuel element for 85 days at 8 MW per element and allowing it to decay for 1 year.

Table 2-9. Nuclides and activity scaling factors for reactor coolant resin from the Test Reactor Area.

Nuclide	Activity scaling factor[a]	Data source
H-3	5.0×10^{-4}	ATR[b]
C-14	4.3×10^{-3}	EPRI (1987)[c]
Fe-55	2.0×10^{-1}	EPRI (1987)
Ni-59	2.8×10^{-3}	ATR[b]
Ni-63	2.8×10^{-1}	ATR[b]
Co-60	6.8×10^{-1}	ATR[b]
Sr-90	2.8×10^{-1}	ATR[b]
Tc-99	1.5×10^{-5}	ATR[b]
I-129	6.8×10^{-8}	Harker (1995b)[d]
Cs-137	3.1×10^{-1}	ATR[b]
Ce-144	6.7×10^{-3}	ATR[b]
Eu-154	7.3×10^{-3}	ATR[b]
Eu-155	3.1×10^{-3}	ATR[b]
U-234	4.2×10^{-6}	Graff (1980) and Schnitzler (1994)[e]
U-235	9.2×10^{-8}	Graff (1980) and Schnitzler (1994)[e]
U-236	1.6×10^{-6}	Graff (1980) and Schnitzler (1994)[e]
Np-237	2.6×10^{-6}	Graff (1980) and Schnitzler (1994)[e]
Pu-238	1.8×10^{-4}	ATR[b]
Pu-239	4.6×10^{-5}	ATR[b]
Pu-240	2.8×10^{-5}	Graff (1980) and Schnitzler (1994)[e]
Pu-241	1.5×10^{-2}	ATR[b]

Table 2-9. (continued).

Nuclide	Activity scaling factor[a]	Data source
Am-241	4.2×10^{-3}	ATR[b]
Cm-242	2.8×10^{-4}	ATR[b]
Cm-244	1.3×10^{-4}	ATR[b]

a. It was assumed that the measured activity was determined by a predominantly gamma-sensitive device (e.g., G-M counter, NaI scintillation detector). As such, only gamma activity was reported. However, there were cases where the gamma activity was increased to account for the beta-emitters. This correction was not universally applied, and in many cases, not even noted. To be conservative, it was assumed that the reported activity (MAP, MFP, and unidentified beta-gama) includes only gamma activity. The scaling factors listed in this table have taken the beta activity into account. Therefore, the sum of the scaling factors is a number greater than unity. The difference between the sum and unity is the relative beta activity. See Harker (1995a) for details on how the scaling factors were derived.

b. Activities scaled to Cs-137 (for H-3, Sr-90, Tc-99, Eu-154 and Eu-155); to Co-60 (for Ni-59 and Ni-63); or to Pu-239 (for Pu-238, Pu-241, Am-241, Cm-242, and Cm-244) as measured for ATR resin shipment 92026 (see Harker and Akers 1994) are assumed to be representative for all resin shipments.

c. Assumed reactor coolant resin C-14 activity relative to Co-60 as reported for pressurized water reactors is representative of the ATR resin C-14 to Co-60 activity ratio.

d. The factor was based on the ratio of I-131 activity to Cs-137 activity in ATR primary coolant water and on ratios of I-129, I-131, and Cs-137 activities calculated with ORIGEN2.

e. ORIGEN2 calculation based on an ATR fuel element irradiated for 85 days at 8 MW per element and allowed to decay for 1 year. Activity is scaled to Pu-239 activity as measured by gamma spectrometry.

Table 2-10. Nuclides and activity scaling factors for sludge waste from the Test Reactor Area.

Nuclide	Activity scaling factor[a]	Data source
H-3[b]	1.0×10^{-1}	EPRI (1987)[c]
C-14	1.0×10^{-2}	EPRI (1987)[c]
Fe-55	7.7×10^{-1}	EPRI (1987)[c]
Co-60	8.7×10^{-1}	EPRI (1987)[c]
Ni-59	4.0×10^{-3}	Resin[d]
Ni-63	3.2×10^{-1}	EPRI (1987)[c]
Sr-90	6.4×10^{-4}	EPRI (1987)[c]
Tc-99	1.1×10^{-4}	EPRI (1987)[c]
I-129	3.0×10^{-8}	Harker (1995b)[e]
Cs-137	1.3×10^{-1}	EPRI (1987)[c]
Ce-144	4.2×10^{-2}	EPRI (1987)[c]
Eu-154	3.1×10^{-3}	Resin[d]
Eu-155	1.3×10^{-3}	Resin[d]
U-234	2.2×10^{-6}	Resin[d]
U-235	4.8×10^{-8}	Resin[d]
U-236	8.5×10^{-7}	Resin[d]
Np-237	1.3×10^{-6}	Resin[d]
Pu-238	3.3×10^{-5}	EPRI (1987)[c]
Pu-239	3.4×10^{-5}	EPRI (1987)[c]
Pu-240	2.1×10^{-5}	Resin[d]
Pu-241	3.7×10^{-3}	EPRI (1987)[c]
Am-241	1.4×10^{-5}	EPRI (1987)[c]
Cm-242	2.7×10^{-5}	EPRI (1987)[c]

Table 2-10. (continued).

Nuclide	Activity scaling factor[a]	Data source
Cm-244	1.3×10^{-5}	EPRI (1987)[c]
U-238	2.9×10^{-9}	Graff (1980) and Schnitzler (1994)[f]

a. It was assumed that the measured activity was determined by a predominantly gamma-sensitive device (e.g., G-M counter, NaI scintillation detector). As such, only gamma activity was reported. However, there were cases where the gamma activity was increased to account for the beta-emitters. This correction was not universally applied and, in many cases, not even noted. To be conservative, it was assumed that the reported activity (MAP, MFP, and unidentified beta-gama) includes only gamma activity. The scaling factors listed in this table have taken the beta activity into account. Therefore, the sum of the scaling factors is a number greater than unity. The difference between the sum and unity is the relative beta activity. See Harker (1995a) for details on how the scaling factors were derived.

b. There is a question as to whether tritium is present at the fraction indicated in this table for all dry waste. Tritium is present in dry waste that has direct contact with the reactor coolant and, in some cases, where there has been secondary contact. The tritium scaling factor listed in this table represents a history of experience with pressurized water reactors and should give numbers that are valid on the average. However, in those cases where there was evidence that tritium was not present or was present in much lower concentrations, the scaling factor for tritium in the table was not used. A note to this effect was placed with that data entry.

c. Sludge waste generated by all commercial pressurized water reactors in the United States.

d. Activities relative to Co-60 (for Ni-59); to Cs-137 (for Eu-154, Eu-155, U-234, U-235, U-236, and Np-237); or to Pu-239 (for Pu-240) are assumed to be the same as those listed for resins (see Table 2-9).

e. The factor was based on the ratio of I-131 activity to Cs-137 activity in ATR primary coolant water and on ratios of I-129, I-131, and Cs-137 activities calculated with ORIGEN2.

f. ORIGEN2 calculation based on an ATR fuel element irradiated for 85 days at 8 MW per element and allowed to decay for 1 year. Activity is scaled to Pu-239 activity as measured by gamma spectrometry.

Table 2-11. Nuclides and activity scaling factors for unidentified alpha-emitters from the Test Reactor Area.

Nuclide	Activity scaling factor[a]
Np-237	2.2×10^{-4}
Pu-238	9.3×10^{-1}
Pu-239	4.0×10^{-3}
Pu-240	2.4×10^{-3}
Pu-242	2.5×10^{-5}
Am-241	2.8×10^{-3}
Cm-242	1.6×10^{-2}
Cm-244	4.4×10^{-2}

a. From ORIGEN2 calculation based on an ATR fuel element irradiated for 85 days at 8 MW per element and allowed to decay for 1 year (Graff 1980; Schnitzler 1994).

does not differentiate between waste classifications according to nuclide composition or classification according to waste stream. For those years, the data entries were made annually. The radionuclide distributions were based on weighted sums of the six waste categories, with the totals equal to the total curies reported for each year. Scaling factors used were based on composite fractions in each waste category derived from waste reports in the following years where differentiation was identified in the waste reports. The calculated nuclide-by-nuclide distribution was entered into the data file for that year.

For the years 1960 to 1983, there are, as a minimum, data entries in RWMIS. Annual reports, topical reports, and letters also indicate waste-generating activities. The latter data were used where possible to verify or replace the data contained in RWMIS. The following approach was used:

- **Reports containing nuclide-by-nuclide distributions.** The individual activities listed in the report were used. In most cases, if an error was not stated, an assumed measurement error was assigned.

- **Reports containing nuclide-by-nuclide distributions plus MAP, MFP, unidentified beta-gamma, and/or unidentified alpha.** The waste was identified as one of the six waste categories listed above. The MAP, MFP, and beta-gamma activities were summed to get a total activity of overall beta/gamma-emitters. A nuclide-by-nuclide

distribution was calculated based on this total activity and the corresponding activity scaling factors for that waste category. The unidentified alpha activity was distributed into individual nuclide activities based on the activity scaling factors listed in Table 2-11 and the total unidentified alpha activity. The reported nuclide distribution, the calculated waste category nuclide distribution, and the calculated alpha nuclide distribution were all added as separate tables.

- **Reports containing only MAP, MFP, unidentified beta-gamma, and/or unidentified alpha.** The waste was identified as one of the six waste categories listed previously. The MAP and MFP activities were summed to arrive at the total beta-gamma activity. A nuclide-by-nuclide activity distribution was calculated based on the total beta-gamma activity and the corresponding activity scaling factors for that waste category. The unidentified alpha activity was divided according to the activity scaling factors listed in Table 2-11. The calculated waste category radionuclide distribution and the calculated unidentified alpha distribution were submitted as separate tables.

- **Reports containing only total activity.** The waste was identified as one of the six waste categories listed above. A nuclide-by-nuclide activity distribution was calculated based on the reported total activity and the corresponding activity scaling factors. The calculated waste category distribution was submitted.

As the preceding and following discussions imply, radionuclide distributions were developed from process knowledge and nuclear physics calculations for each category of waste stream. Therefore, no single, uniform assumption was used for the distribution of generic radioactivity terms such as MAP and MFP in shipping records.

Two entries for the same radionuclide in the same year appear on the data sheets for some TRA waste streams. In these cases, the bounds differ on the entries because parts of the total activity were determined using different methods. For example, two entries for Cs-137 in a waste stream for a given year were obtained using laboratory measurements and by distributing a MFP term using scaling factors.

Description of Waste Streams. The TRA waste was divided into a total of 40 waste streams (see Table 2-12). The eight most important waste streams from TRA are discussed in detail below. For each of these streams, the discussion tells how the stream was generated, the principal contaminants in the stream, the specific information sources reviewed and used, and the assumptions and analysis used to estimate the quantities of the contaminants.

TRA-603-1H (Resins)

- **Generation of the waste stream.** Resins are used to purify the reactor coolant water. They capture and immobilize activation and fission products. When their useful capacity for ion exchange has been reached, they are removed and become waste.

- **Principal radiological contaminants.** The major radiological contaminants in this waste stream are Co-60, Ni-63, Cs-137, and Sr-90.

Table 2-12. Waste streams originating at the Test Reactor Area.

Waste stream number	Description of waste
TRA-603-1H	Resins
TRA-603-3H	Irradiated end boxes
TRA-603-4H	Core and loop components
TRA-603-5H	Uranium in metal
TRA-603-6H	Sludge
TRA-603-7H	Glass
TRA-603-8H	Radioactive sources
TRA-603-9H	Irradiated fuel
TRA-603-10H	Asbestos
TRA-603-11H	Meat contaminated with botulinus
TRA-603-12H	Vermiculite
TRA-603-13H	Filters
TRA-603-14H	Continuous air monitors
TRA-603-15H	Metal (aluminum, stainless steel, zircaloy, beryllium, and cadmium)
TRA-603-16H	Paper
TRA-603-17H	Dirt
TRA-603-18H	Rags, floor sweepings, and glassware
TRA-603-19H	Concrete, metals, and wood
TRA-603-20H	Wood
TRA-603-21H	Construction materials, concrete, brick, sand, soil, and asphalt

Table 2-12. (continued).

Waste stream number	Description of waste
TRA-603-22H	Rags, floor sweepings, and glassware
TRA-603-23H	Terphenyl (Santo-wax)
TRA-603-24H	Gas bottles
TRA-603-25H	Sodium
TRA-603-26H	Lead
TRA-604-1H	Uranium powder
TRA-614-1H	Capsules of graphite, nickel, and scrap U-235
TRA-614-2H	Continuous air tank
TRA-632-1H	Core structural pieces
TRA-642-1H	Fission chambers with foils
TRA-642-2H	Insulation
TRA-642-3H	Hydrofluoric acid solidified and neutralized as NaF
TRA-642-4H	Rags, paper, and wipes
TRA-642-5H	Irradiated fuel rods
TRA-642-6H	Scrap metal pieces
TRA-642-7H	Various combustible materials
TRA-653-1H	Benzine
TRA-670-1H	Beryllium reflectors from the MTR, ETR, and ATR
TRA-670-2H	Stainless steel and aluminum
TRA-706-1H	Tank

- **Information sources reviewed and used.** Information sources reviewed and used include Abrashoff (1992a, 1992b); Beatty (1992a, 1992b); Brower (1992); Schnitzler (1994); and Vance and Associates (1992).

- **Assumptions and analysis.** The total radioactivity is taken from the sources cited. The distribution of radionuclides is that given in Table 2-9. The distribution was assumed to be the same for the MTR, ETR, and ATR. The analysis assumed that the amount of radioactivity in the resins was proportional to total reactor power.

TRA-603-4H (Core and loop components)

- **Generation of the waste stream.** This waste stream is comprised of material that was in or very near the reactor core. The material has been subjected to extreme neutron and gamma-ray exposures.

- **Principal radiological contaminants.** The large amounts of stainless steel contain Co-60 and Ni-63, and they are also contaminated with fission products because of the proximity to the core. The principal fission products are Sr-90 and Cs-137.

- **Information sources reviewed and used.** Information sources reviewed and used are Osloond (1965), annual reports of the AEC Health and Safety Division, DOE radioactive waste management information reports, and RWMIS.

- **Assumption and analysis.** The total radioactivity is taken from the sources cited. The distribution of radionuclides is that given in Table 2-8.

TRA-603-5H (Uranium in metal)

- **Generation of the waste stream.** This material came mostly from activities performed in the metallurgy and chemistry laboratories at TRA.

- **Principal radiological contaminants.** The principal radiological contaminants include the various nuclides of uranium: U-232, U-233, U-234, U-235, and U-238.

- **Information sources reviewed and used.** Information sources reviewed and used are Osloond (1965), annual reports of the AEC Health and Safety Division, DOE radioactive waste management information reports, and RWMIS.

- **Assumption and analysis.** If an information source indicates depleted uranium, the uranium was assumed to be U-238; natural uranium was not encountered. Entries other than special forms were assumed to be highly enriched uranium. Special forms of U-232 and U-233 were entered only if specifically identified. The majority of the entries are for highly enriched uranium; the nuclide activity distribution was taken from Table 2-6.

TRA-603-15H (Metal)

- **Generation of the waste stream.** This waste stream contains contaminated metals that are not stated to be core or loop components or canal trash. Cadmium, for example, was used as a neutron shield and absorber in loop cubicles. It became contaminated and was disposed of when a cubicle was cleaned.

- **Principal radiological contaminants.** The principal radiological contaminants of this waste stream are the activation products Co-60, Ni-59, and Ni-63 and the fission products Cs-137 and Sr-90.

- **Principal nonradiological contaminants.** Cadmium is the principal nonradiological contaminant in this stream.

- **Information sources reviewed and used.** Information sources reviewed and used are Osloond (1965), annual reports of the AEC Health and Safety Division, DOE radioactive waste management information reports, and RWMIS. An unpublished scoping report on the HDT by an expert committee led by R. L. Nitschke was used to gain information about cadmium. [The report is an attachment to a letter from R. L. Norland to D. W. MacDonald (Norland 1993)].

- **Assumptions and analysis.** The total radioactivity is taken from the sources cited. The nuclide activity distribution is assumed to be that contained in Table 2-8. Information in RWMIS and the expert committee report were used to assess cadmium disposal.

TRA-603-16H (Paper)

- **Generation of the waste stream.** This waste stream category includes blotting paper used during reactor shutdown to prevent the spread of contamination. It was also used to soak up spills of highly contaminated water. Some contaminated wood is included.

- **Principal radiological contaminants.** The principal radiological contaminants of this waste stream are Co-60, Ni-63, Cs-137, and Sr-90.

- **Information sources reviewed and used.** Information sources reviewed and used are Osloond (1965), annual reports of the AEC Health and Safety Division, DOE radioactive waste management information reports, and RWMIS.

- **Assumptions and analysis.** The total radioactivity is taken from the sources cited. The nuclide activity distribution is assumed to be that contained in Table 2-8.

TRA-603-18H (Rags, floor sweepings, etc.)

- **Generation of the waste stream.** This waste stream contains items used to clean up after spills or after a shutdown.

- **Principal radiological contaminants.** The principal radiological contaminants of this waste stream are Co-60, Ni-63, Cs-137, and Sr-90.

- **Information sources reviewed and used.** Information sources reviewed and used are Osloond (1965), annual reports of the Health and Safety Division, radioactive waste management information reports, and RWMIS.

- **Assumption and analysis.** The total radioactivity is taken from the above sources. The nuclide activity distribution is assumed to be that contained in Table 2-8.

TRA-603-20H (Wood)

- **Generation of the waste stream.** A large portion of this waste stream is wood from the MTR and ETR cooling towers. This wood was contaminated because of small primary and secondary breaks over the years.

- **Principal radiological contaminants.** The principal radioactive contaminants of this waste stream are Co-60, Ni-63, Cs-137, and Sr-90.

- **Information sources reviewed and used.** Information for this stream was obtained from White (1975), RWMIS, and interviews with former employees.

- **Assumptions and analysis.** The total radioactivity is taken from the sources cited. The nuclide radioactivity distribution is assumed to be that contained in Table 2-8.

TRA-670-1H (Beryllium reflectors)

- **Generation of the waste stream.** The beryllium reflectors in this waste stream were used around the reactor core to reflect escaping neutrons back into the core. They were subject to very high neutron fluences.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are H-3 and Be-10.

- **Principal nonradiological contaminants.** Beryllium is the principal nonradiological contaminant in this stream.

- **Information sources reviewed and used.** Information sources reviewed and used were a letter from P. K. Nagata to T. H. Smith on December 22, 1993 (Nagata 1993), a letter from T. A. Tomberlin to D. E. Sheldon on December 22, 1986 (Tomberlin 1986), annual reports of the AEC Health and Safety Division, and DOE radioactive waste management information reports. Information from the unpublished expert committee report on the HDT (see attachment in Norland 1993) was also used.

- **Assumptions and analysis.** The mass of beryllium sent to the RWMC was correct on the shipping records, as confirmed by the calculations of Nagata (1993). The radioactivity

was based on results in Nagata (1993). Nagata's method for estimating the tritium activity in the reflectors was based on Tomberlin's calculation of the tritium generation rate per unit volume of beryllium. Although disposal of the reflectors occurred between 1969 and 1977, generation of the tritium in these reflectors was occurring fairly steadily from about 1963 through 1977. The reflectors were in the reactors and in storage canals at the reactor facilities for various periods of time before being shipped for disposal. In the absence of readily available, detailed histories of each reflector, the simplifying assumption was made that the tritium (and other radionuclides) produced in the reflectors was generated at a uniform rate from 1963 through 1977.

During the operating period of the MTR and ETR, carbon tetrachloride was a popular cleaning solvent. Carbon tetrachloride was used on external parts of the reactor. It is not known how much carbon tetrachloride was used to clean contaminated external reactor parts. Most carbon tetrachloride used at TRA probably went to the sanitary landfill as nonradioactive waste. However, a small amount may have gone to the RWMC on contaminated rags, paper, etc. One RWMC worker reported that 500-gal lots of solvent were sent from the TRA metallurgical laboratory to the RWMC in the 1950s and 1960s. The nature of the solvent was not known. A former employee of the TRA metallurgic laboratory was interviewed, however, and no confirmation or refutation of the presence of carbon tetrachloride was obtained. Thus, no reliable data are available concerning this contaminant in TRA waste buried in the SDA.

2.4.3 Idaho Chemical Processing Plant

The Generator. ICPP is located near the center of the INEL between CFA and TRA (see Figure 2-1). The primary purpose of this facility was to recover U-235 from expended military and test reactor fuel.

The facility originally included a storage pool, housed in a separate building, to store the fuel under water until a processing campaign was underway. A process building contained dissolvers to dissolve the fuel assemblies in nitric and hydrofluoric acids and a solvent extraction system that used tributyl phosphate, hexone, and nitric acid to recover the uranium. Laboratory, water treatment, and evaporator facilities were also a part of the complex.

In the early 1960s, a fluidized bed calciner was constructed and operated to convert the highly radioactive waste (resulting from the processing of fuel) to a granular solid. This facility was replaced by the New Waste Calcining Facility in the late 1970s.

In the early 1970s, an improved and larger fuel storage pool facility was constructed and placed into operation. About 1973, a new building was constructed and joined onto the original fuel storage facility to store dry graphite-type fuels, for which no uranium recovery process existed.

In 1992, a decision was made by DOE to discontinue the processing of all fuels at ICPP. Since then, operations at ICPP have been limited to the storage of spent fuel and the calcination and storage of high-level liquid waste.

Generation of the Waste. Most of the radioactive waste produced at ICPP remains in storage at that facility. Raffinates resulting from the dissolution and processing of nuclear fuels, waste

solutions resulting from the decontamination of process cells, and waste solutions produced by concentrating radioactive liquids in the process equipment waste evaporator are stored in underground stainless-steel tanks. This waste is later processed in the fluidized bed calciner at ICPP to convert the liquid to a granular solid. This processing of irradiated fuels produced thousands of gallons of high-level liquid waste containing several million curies of radionuclides. These radionuclides were nearly all retained at ICPP, either as liquid waste stored in underground stainless-steel tanks or as granular solids stored in underground stainless-steel bins.

Several processes at ICPP, however, produced waste that was sent to the RWMC for burial. These processes included

- Removing end pieces from Experimental Breeder Reactor-II (EBR-II) fuel assemblies before processing.
- Removing several years' accumulation of sludge from the CPP-603 fuel storage basin.
- Leaching of Vycor glass, which was contaminated with uranium and radionuclides from the EBR-II pyrometallurgical process.
- Replacing off-gas filters from the off-gas cleaning system of the Waste Calcining Facility after they became loaded with particulate matter.
- Dissolving small quantities of irradiated Navy fuel pieces in the Multicurie Cell to test uranium dissolution flowsheets.
- Operating laboratory and decontamination facilities.
- Using nonregenerable inorganic ion-exchange materials to remove radiological contaminants from fuel storage basin water, which resulted in the ion-exchange material becoming a waste stream.
- Using lead bricks and lead sheets for shielding in areas subject to radiological contamination.
- Conducting "cold testing" of the uranium solvent extraction systems using nonradioactive fuel materials and large quantities of chemical solutions.
- Removing soil and building exterior structural materials contaminated with localized deposits of radioactive particles from inadvertent airborne releases.
- Leaking in underground piping that carried highly radioactive solutions.
- Accumulating zirconium metal scrap for "cold testing" uranium recovery or waste calcination flowsheets. The excess material became a waste stream.

General Availability of Information. For waste produced before 1960, letters, special work permit forms, and the early types of waste shipment forms were found. For liquid waste disposed of

in the Acid Pit, waste disposal records were the only source of information located. For liquid waste in which the concentrations were not recorded, values were assigned based on the process believed to have produced the waste.

For waste produced in the post-1960 years, reports that were used included Batchelder (1984), DOE (1973), Hoech and Rhodes (1979), Jorgensen (1992), Liekhus (1992), Modrow and Lakey (1964), Osloond (1970), PPCo (1963), Plansky and Hoiland (1992), and Rhodes (1981). In addition, RWMIS, individual waste shipment records, and interviews with early waste handlers were used as appropriate.

Where the radiological contaminant was listed as MFP or unidentified beta-gamma, the breakdown into individual radionuclides (unless otherwise indicated) was that given in Plansky and Hoiland (1992). This breakdown is 10% Sr-90, 10% Y-90, 3.1% Zr-95, 3.1% Nb-95, 10% Cs-137, 19.7% Ce-144, 19.7% Pr-144, 4.4% Sb-125, 10% Ru-106, and 10% Rh-106. This breakdown, supplied by ICPP personnel, was reported to be valid for all time periods. It is assumed that this is a valid breakdown because, except for the fuel end pieces, essentially all of the radiological waste originated from solutions produced by the dissolution and solvent extraction or storage of aged fuel elements, which did not differ appreciably in fission product content. The breakdown for MAP in ICPP waste from ANL-W fuel end pieces was supplied by ANL-W personnel as reported in Plansky and Hoiland (1992), which is 50% Co-58 and 50% Mn-54. There were no entries for unidentified alpha radionuclides.

Data-Collection Approach. The general data-collection approach used was to review any documents that might contain process information pertaining to an individual waste stream and compare this information with data obtained from the individual waste shipping records and RWMIS. Where possible, individuals familiar with the process that produced the waste stream were interviewed. In some cases, assumptions were made on the basis of these interviews or from the data gatherer's personal knowledge of the process.

Description of Waste Streams. The ICPP waste was divided into 15 waste streams (see Table 2-13). The nine most important waste streams from ICPP are discussed in detail below. For each of these streams, the discussion tells how the stream was generated, the principal contaminants in the stream, the specific information sources reviewed and used, and the assumptions and analysis used to estimate the quantities of the contaminants.

CPP-601-1H (Leached Vycor glass)

- **Generation of the waste stream.** One of the initial goals of the EBR-II facility was to process the expended fuel from the EBR-II reactor by a pyrometallurgical process. In this process, the uranium was recovered and used to fabricate new fuel elements. One step in this process was to pour the molten uranium into Vycor glass molds to form the new fuel elements. When the uranium solidified, the Vycor glass mold was crushed and the fuel element was removed. Some uranium and a considerable amount of fission products remained attached to the crushed glass. This crushed glass was shipped in a shielded container to ICPP, where it was leached with hot nitric acid to recover the uranium remaining attached to the glass. The uranium was processed through the ICPP uranium recovery systems, and the Vycor glass was shipped to the RWMC for disposal.

Table 2-13. Waste streams originating at the Idaho Chemical Processing Plant.

Waste stream number	Description of waste
CPP-601-1H	Leached Vycor glass
CPP-601-2H	Insulation, pipe, wire, wood, plastic, rags, and concrete
CPP-601-3H	Dissolved fuel specimens
CPP-601-4H	Acidic aqueous liquid
CPP-601-5H	Organic solvents
CPP-601-6H	Pipe, glass, gloves, cans, vessels wire, valves, paper, metal, wood, clothing, filters, plastic bottles, and rubber
CPP-601-7H	Zirconium and zirconium-uranium alloy
CPP-603-1H	Fuel end pieces
CPP-603-2H	Lead
CPP-603-3H	Fuel storage pool sludge
CPP-603-4H	Decontamination chemicals
CPP-603-5H	Zeolite
CPP-603-6H	Contaminated roof materials and top soil
CPP-604-1H	Surface soil
CPP-633-1H	High-efficiency particulate air filters

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Cs-137, Ce-144, Sr-90, and Cs-134.

- **Information sources reviewed and used.** The values for each waste shipment were reported on the individual waste shipping records and in RWMIS. No other source of information for this waste was found. A personal interview with Morse Jacobson, who performed the leaching in the Multicurie (shielded) Cell, indicated that the only information about the contents was probably that on the waste shipment records. The main concern at the time was recovery of the uranium.

- **Assumptions and analysis.** Some of the glass reported on the waste shipment records may not have been from the EBR-II process, but it was not possible to distinguish other glass from the EBR-II glass. Therefore, it was assumed that all of the glass that came from the Multicurie Cell was EBR-II glass. Because the EBR-II leaching process took place over a period of several years, it is likely that the majority of the glass was from EBR-II. The MFP values were believed to have been obtained by converting radiation readings and using other information.

CPP-601-3H (Dissolved Navy fuel specimens)

- **Generation of the waste stream.** In 1969, experiments to develop a dissolution process for Navy fuel that had been irradiated in the ETR were run in the Multicurie Cell at ICPP. It was necessary to use a shielded cell facility because the fuel specimens used were highly radioactive. After the experiments were completed, the total solution produced (including the U-235) was reacted with plaster of Paris in polyethylene bottles to produce a solid, and the resulting solid was transported to the RWMC for disposal. This was a one-time operation, but it produced a significant quantity of radiological contaminants.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Sr-90, Y-90, Zr-95, Nb-95, Cs-137, Ce-144, Pr-144, Sb-125, Ru-106, Rh-106, U-238, U-234, and U-235.

- **Information sources reviewed and used.** Only one waste disposal record was used to identify this waste stream, and only a total curie value was reported. The values for the individual radiological contaminants were obtained by using the radionuclide distribution given in Plansky and Hoiland (1992) for ICPP to break down the total curies for the shipment. Osloond (1970) was used to make a comparison, as described below. Additional information was obtained from a personal interview with L. A. Decker, who performed the experiment.

- **Assumptions and analysis.** L. A. Decker indicated that the reactor history of the fuel specimens was well known. The reactor history and radiation measurements were used to establish the value for the total curies. The uranium value was believed to have been obtained from a radiochemical analysis. Although this was a one-time experiment, it produced about 96% of the total curies from ICPP that were buried in the RWMC in 1969, using the total curie values reported for ICPP in Osloond (1970) for 1969.

CPP-601-4H (Aqueous chemicals)

- **Generation of the waste stream.** In the 1950s, a pit outside the RWMC boundary was used to dispose of chemical solutions used in cold runs for testing chemical processes or originating from laboratory activities. When acid solutions were disposed of, large quantities of lime were added to the pit to neutralize the acid. About 1960, the boundaries of the RWMC were changed and use of the Acid Pit, which was enclosed within the new boundaries, was discontinued. All of the INEL facilities used this pit to some extent. This liquid waste contained very low levels of radioactivity. Some of the waste was generated in the Chemical Engineering Laboratory, which was located at CFA. The facility was operated by ICPP personnel testing ICPP processes; therefore, the waste produced was reported as an ICPP waste stream.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this waste stream are nitric acid, aluminum nitrate nonahydrate, mercuric nitrate monohydrate, uranyl nitrate, sodium nitrate, hydrofluoric acid, sulfuric acid, chromium, beryllium, and copper nitrate.

- **Information sources reviewed and used.** Information for this waste stream was obtained from individual records prepared at the time of waste shipment. These records included special work permits and waste disposal forms of different types. Jorgensen (1992) contained a listing of the waste, but this listing was taken from the individual waste shipment records. A personal interview with M. Young (retired) provided additional information.

- **Assumptions and analysis.** The chemicals and their concentrations were taken from the individual records, where possible. The concentrations frequently were not given; therefore, concentrations were assigned based on the process that was believed to have produced the waste. In at least one case, neither the chemicals nor concentrations were given for several large shipments from ICPP, totaling about 22,100 gal. The contents of these shipments were identified by a personal interview with M. Young, who had signed many of the waste shipment forms. This waste was from a cold, full-scale process run at ICPP, so a chemical composition and concentration values for the chemicals were assigned on that basis (1.0 molar nitric acid and 1.2 molar aluminum nitrate nonahydrate).

CPP-601-7H (Zirconium metal)

- **Generation of the waste stream.** In the early 1960s, a large quantity of zirconium and zirconium alloy metal scrap was shipped to ICPP for full-scale testing of dissolution and solvent extraction flowsheets for zirconium and zirconium alloy reactor fuels. When this testing was completed, the remaining metal was stored outside in wooden boxes and metal drums for several years. In 1967, this material was shipped to the RWMC for burial.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this waste stream are zirconium and zirconium alloy. Some natural uranium was reported to be in the shipment, but it was not stated whether this was alloyed with the zirconium.

- **Information sources reviewed and used.** Two waste shipping forms and RWMIS contained information pertaining to the shipment of zirconium to the RWMC. Liekhus (1992) reported this material was buried in Pit 9, but the information in that document was obtained from RWMIS and waste shipment records. A personal interview with L. O. Zohner at ICPP also provided some information.

- **Assumptions and analysis.** Most of the zirconium was listed on one waste shipment record. This record listed the weight as 30,000 to 40,000 lb. The mean value of 35,000 lb was used for the weight of the zirconium, so the uncertainty would be ±5,000 lb or 14%. Because the weight was probably estimated, the uncertainty was increased to ±20% to account for error in estimating the weight. The second waste shipment record listed 3,400 lb of zirconium and 182 kg of natural uranium. The 3,400 lb was added to the 35,000 lb to bring the total to 38,400 lb. Liekhus (1992) listed the zirconium content as 15,000 kg (33,000 lb). In estimating the weight of the metals for his report, Liekhus subtracted the weight of the containers, which may account for the lower value.

CPP-603-1H (Fuel end pieces)

- **Generation of the waste stream.** To process the EBR-II stainless-steel-clad fuel, the end pieces, which did not contain uranium, were cut off in the fuel storage basin. Thus, when the fuel was processed, this excess stainless steel did not have to be dissolved. The end pieces were collected and stored in containers on the floor of the fuel storage basin. At the end of the two EBR-II fuel processing campaigns in 1973 and 1982, the end pieces were loaded into a shielded cask and disposed of at the RWMC.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are activation products produced by the reaction of neutrons with the components of the stainless steel. These radionuclides were identified as Co-60, Co-58, Cr-51, Fe-59, and Mn-54 on the waste disposal records. Technetium-99, C-14, Nb-94, Ni-63, Ni-59, and Zr-93 were later shown to be present in this type of waste. These latter radionuclides were not identified earlier because they were either present in very low concentrations or were weak beta-emitters, or both. They were not important for determining the shielding required to transport the waste, but they may be important for a risk assessment because of their long half-lives. The concentrations of these latter radionuclides were calculated as described below.

- **Information sources reviewed and used.** The information sources used to obtain the values for the preceding radionuclides included Batchelder (1984), DOE (1973), the individual waste shipping records, RWMIS, calculations, and a personal interview with L. W. Madsen, the operator who handled the equipment used to cut and ship the end pieces. The documents showed large values of radioactivity from ICPP in 1973 and 1982, the years the fuel end pieces were disposed of. The values for Co-60 and Co-58 reported in DOE (1973) agreed with the total values reported on the individual waste records. However, the document did not break down the radioactivity into individual waste streams. The most detailed information was obtained from RWMIS and the individual shipping records. The concentrations of some of the radionuclides (Ni-63, Tc-99, C-14, Nb-94,

Ni-59, and Zr-93) were obtained from calculations made by using the ratio of Co-60 to Ni-63 to calculate the activity of Ni-63 and then using the ratio of Ni-63 to the nuclide in question to calculate the activity for that nuclide. These ratios were calculated by using DOE (1992) to estimate the quantities of these neutron activation products in the stainless-steel structural materials.

- **Assumptions and analysis.** Although no analytical records were found, the breakdown of radionuclides reported on the waste records probably came from a laboratory analysis of a dissolver product sample. The dissolver product solution had to be sampled to track the U-235 inventory. Thus, it would have been a simple matter to use this sample also for a total radionuclide inventory, which was required at this time for waste shipments transported to the RWMC. This analysis probably would have been accurate to within 10%, but the weight of the end pieces was estimated, and it was assumed that this value could have been off by as much as 50%. This reasoning was used to determine the maximum and minimum values. In addition, the 23,075 Ci of MAP was distributed among the principal radionuclides in the waste according to the distribution suggested by EBR-II personnel in Plansky and Hoiland (1992). The suggested breakdown was 50% Co-58 and 50% Mn-54.

CPP-603-2H (Lead)

- **Generation of the waste stream.** Lead bricks and lead sheets were commonly used at the INEL to provide shielding from radiation arising from experiments or operational activities. In addition, lead is used as shielding in containers for transporting radioactive samples or fuel materials. When the lead became sufficiently contaminated with radionuclides to create a potential contamination or radiation problem, it was sometimes decontaminated for reuse; however, frequently it was transported to the RWMC for burial.

- **Principal nonradiological contaminants.** The principal nonradiological contaminant in this waste stream is lead.

- **Information sources reviewed and used.** Osloond (1970) includes a summary of the solid waste disposed of at the RWMC during the time period 1952 through 1969. Batchelder (1984) provides similar information for the time period 1952 through 1983. The lead bricks were disposed of in 1978, and the lead sheets and other materials were disposed of from 1960 through 1977. However, Osloond (1970) and Batchelder (1984) provide only summary tables of radioactivity and volumes, and they do not specify what materials made up these values. The principal source of information for the disposal of the lead was the individual waste shipment records and RWMIS.

- **Assumptions and analysis.** The lead bricks were of uniform size and weight, so it was assumed that the total number of bricks multiplied by the weight of one brick would give a weight within 10%. The lead sheets would have been more difficult to assign a weight to, but it was assumed that this value would be within 25%. The weight of the lead was obtained from the individual waste shipment records.

CPP-603-3H (Sludge from the fuel storage basin)

- **Generation of the waste stream.** The CPP-603 fuel storage basin consists of three concrete basins interconnected by a transfer canal, all housed in the CPP-603 building. The basin contained water to a depth of about 6 m (20 ft) to provide shielding for the radioactive fuel. The building consists of a steel frame covered with transite panels. There was no seal where the roof and the walls intersected and large rollup doors were opened frequently; therefore, windblown dust entered the building and settled to the floor of the basin.

  Two of the basins were covered with a steel grating that corroded and dropped iron oxide particles into the water. Additionally, galvanized yokes and hangers extended from an overhead monorail to a point just above the floor of the basin. Galvanized steel buckets were attached to these yokes and contained the irradiated fuel elements. The galvanized steel also corroded and released particulate matter into the water.

  Over a period of about 26 years, a 5- to 10-cm (2- to 4-in.) layer of sludge accumulated on the floor of the basin. This sludge had ion-exchange properties, which caused it to sorb radionuclides released into the water from leaking fuel materials. The sludge made the water cloudy when fuel was moved, making it difficult to handle the fuel safely. It also contaminated shipping casks, which posed a radiation hazard to personnel when the casks were removed from the water for decontamination before shipping.

  The sludge was removed from the basin using an underwater vacuum system. The sludge was then transported through a flexible line to a hydroclone, where it was separated into (a) a concentrated sludge, which was placed in temporary storage in a large stainless-steel tank, and (b) water containing finely divided solids, which was returned to the inlet of the multimedia filters. Later, the sludge was pumped from the sludge storage tank into concrete steel-lined vaults, where it was dewatered and solidified, then buried at the RWMC.

- **Principal radiological contaminants.** The radiological contaminants in this waste stream are Ce-141, Ce-144, Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, Zr-95, Ru-106, Sb-125, Sr-90, U-234, U-235, U-236, U-238, Y-90, Nb-95, Pr-144, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, and Rh-106.

- **Information sources reviewed and used.** The information sources used include Hoech and Rhodes (1979), RWMIS, and individual waste shipment records. A personal interview with L. W. Madsen provided information on the process that was used. Batchelder (1984) was reviewed, but it did not contain a breakdown of the ICPP waste by streams, so it was not used.

- **Assumptions and analysis.** Hoech and Rhodes (1979) reported that the sludge was sampled on the basin floor before vacuuming and in the storage tank that collected the concentrate from the hydroclone during the vacuuming process. It was assumed that the concentrations of the radionuclides reported on the waste shipping records and from RWMIS came from laboratory analyses of these samples. Because the analyses were likely

done in the ICPP analytical laboratory and the sludge was thoroughly mixed during the vacuuming process, it was assumed that the results were accurate within 20%.

CPP-604-1H (Contaminated soil)

- **Generation of the waste stream.** In 1974, during the course of drilling in the ICPP tank farm to install cathodic protection electrodes, a high concentration of radiological contamination was encountered at a point approximately 2 m (7 ft) below grade. Approximately 43 m^3 (56 yd^3) of contaminated soil containing about 3,000 Ci of radiological contamination was excavated, packaged, and transported from the tank farm to the RWMC. Subsequent examination revealed that the contamination came from a first-cycle waste stream that leaked through a small hole in piping that transported waste from the process building to the high-level waste tanks.

  Soil from several other contamination incidents of lesser magnitude was included as part of this waste stream.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Ce-144, Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, Mn-54, Pr-144, Pu-238, Pu-239, Ru-106, Rh-106, Sb-125, Sr-90, Y-90, Zr-95, and Nb-95.

- **Information sources reviewed and used.** The principal source of information was a report entitled *ICPP Tank Farm Contaminated Soil Incident*, dated October 1, 1974. This report does not have a document number, but it is attached to a letter from F. H. Anderson to R. Glenn Bradley (Anderson 1975). RWMIS was used to obtain values for the radiological contaminants for the smaller soil incidents. Plansky and Hoiland (1992) was used to distribute the MFP among the various radionuclides. Batchelder (1984) was reviewed. It covered the time period of interest but did not list individual waste streams, so it was not used.

- **Assumptions and analysis.** A laboratory analysis of the soil for the radiological contaminants (as reported in the tank farm document) was used to identify the contaminants. It was assumed that the total amounts could be estimated by multiplying the known volume of spilled liquid by the concentration of the contaminants in the liquid. RWMIS was used to obtain values for the radiological contaminants for the smaller soil contamination incidents. Because of the lack of detailed information on the smaller incidents, the uncertainty for the radiological contaminants was considered to be $\pm 50\%$.

CPP-633-1H (Filters from the Waste Calcining Facility)

- **Generation of the waste stream.** Filters were used in the Waste Calcining Facility off-gas system as a final barrier to prevent the atmospheric release of any particulate matter (calcine) in the off-gas. When the pressure drop across the filters became excessive, the filters were replaced and the old filters were disposed of at the RWMC.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Ce-144, Cs-137, Nb-95, Pr-144, Rh-106, Ru-106, Sb-125, Sr-90, Y-90, and Zr-95.

- **Information sources reviewed and used.** Sources of information reviewed were Modrow and Lakey (1964), Phillips Petroleum Company (1963), individual waste shipment records, and RWMIS. Information was also obtained from a personal interview with Barry O'Brien at ICPP.

- **Assumptions and analysis.** The radiological contaminants and their concentrations were listed on the individual waste shipment records and in RWMIS. Modrow and Lakey (1964) indicated that a small side stream of the off-gas was pulled through a Millipore filter, and this sample was analyzed in the laboratory.

2.4.4 Naval Reactors Facility

The Generator. NRF is located in the western part of the INEL, about 23 km (14 mi) north-northeast of the RWMC (see Figure 2-1).

NRF was established in 1950 when construction began on the prototype power plant for the U.S. Navy's first nuclear-powered submarine, the USS Nautilus. This prototype, later named S1W, was developed to test the propulsion plant design and to train Navy personnel to operate reactors in preparation for duty on nuclear-powered submarines and ships in the fleet. Two additional naval reactor prototypes were subsequently built at NRF: A1W in 1957 and S5G in 1965. The basic mission of these other prototypes was the same as for the original prototype—to test propulsion plant designs and to train Navy personnel. The S1W plant was shut down in October 1989, A1W was shut down in January 1994, and the S5G plant was shut down in May 1995.

The ECF, built at NRF in 1958, was designed to receive irradiated naval reactor fuel, perform examinations on the fuel elements, remove excess structural material from the fuel elements, and transfer the fuel elements to ICPP. The ECF has also received and examined naval fuel test specimens that have been irradiated in other reactors, such as the ATR. The fuels are remotely handled under water in the ECF water pits. The water serves as a transparent shielding medium in which a number of procedures can be carried out, including disassembling, cutting, sawing, milling, and visually examining various parts of the fuel elements. Some procedures are also carried out in hot cells at ECF.

Generation of the Waste. LLW is generated by the naval reactor prototypes as a result of activities such as reactor coolant sampling, maintenance, repair, and refueling, these actions require interface with the contaminated plant internals. LLW is generated at ECF as a result of fuel examination work. The majority of the waste originating at the prototype plants is compactible waste (e.g., plastic bags, rubber gloves, blotter paper, and other materials used to contain contamination) with very low levels of radioactivity. In addition to this compactible and largely incinerable waste, there have also been occasional metal valves and piping sections that are not compactible and that can contain higher quantities of radioactivity. Metal tanks and drums containing spent ion-exchange resins and sludge from water processing systems add to the noncompactible component of the waste streams.

The majority of both the radioactivity (curies) and the volume of waste that has been transferred from NRF to the RWMC has come from ECF. Most of the radioactivity emerging from ECF is in highly corrosion-resistant metal structural materials removed during the naval fuel examinations. This material is loaded into metal containers which, in turn, fit into large shielded shipping casks. These casks are then taken to the RWMC, where the containers are removed and buried.

General Availability of Information. The main source of data pertaining to waste shipments from NRF is the RWMIS database of shipping and disposal records, as amended by information from Bartolomucci (1989). In addition, over 20 other documents (such as reports, engineering design files, and letters) were examined in a search for additional or corroborating data. Copies of the original waste transfer records were also scanned for specific data. Nieslanik (1994), Bartolomucci (1989), and RWMIS provided most of the data used. The two documents contain the results of extensive analyses by NRF and Bettis Atomic Power Laboratory personnel based on reactor operating histories and nuclear physics calculations. Vigil (1990) contained some expository material that validated the data gatherer's recollection of how the scrap casks from ECF were handled.

Earlier records, especially for the period before 1960, have been difficult to find. When they do exist, they often lack information of interest to this task. For example, there is little information on the existence of hazardous chemicals, such as lead and asbestos. The information on hazardous chemicals can sometimes be deduced, however, from other information in the records and from interviews with former NRF and RWMC workers.

Another problem with the early records is the lack of information on radionuclide content. In the early years, the waste transfer forms were limited to recording information of interest to people handling the waste, such as the radiation level, a brief description of the material, approval signatures, and date. Later, the forms recorded estimates of activity in the shipment, usually listing Fe-59 or Co-60 as the only nuclide.

The assumption that Co-60 was the predominant nuclide was probably accurate, but that assumption overlooked the possibility that other contributors were present as well, and information on the other contributors is not available now. Only in recent years has waste material been subjected to isotopic analysis, providing a more accurate estimate of the activity and radionuclide distribution. One end result of these gaps in the records is that there is a great deal of uncertainty regarding the radionuclide content of the waste, as previously discussed.

Two important sources of information on the NRF waste are the two letters issued by NRF: Bartolomucci (1989) and Nieslanik (1994). These two letters document efforts made by NRF to improve the information available on (a) the distribution of radionuclides within the identified NRF waste and (b) the total number of curies shipped from NRF in the scrap casks from 1955 through 1983. Between 1955 and the time when ECF began operations, some core structural scrap was shipped from the S1W building. Nieslanik (1994) documents all of the scrap shipped from 1955 through 1975.

The method used by NRF to determine the total activity and radionuclide distribution in scrap cask inserts shipped from ECF from 1976 through 1989 was outlined in Bartolomucci (1989). This method was based on knowledge of the metal alloys in the reactor core structural materials and the reactor core radiation history. This information allowed NRF to calculate the extent of expected

neutron activation of the core structural material. As pointed out in Bartolomuicci (1989), this technique is similar to the calculation methods used to determine power levels and lifetimes for nuclear cores, and it has been validated empirically. The same method was used for the scrap cask shipments from 1955 through 1975 that were provided in Nieslanik (1994).

Data-Collection Approach. The approach selected for data collection for the NRF waste was initially to take data from both the RWMIS database and the original waste transfer records. The figures from both sources were frequently checked against each other, helping to resolve conflicts and answer questions that arose during the investigation. Computer-aided searches of the database were augmented and spot-checked by referring to copies of the original records. A limited amount of information was obtained from former workers, although these people were generally unable to recall specific details regarding events that took place decades ago. These sources *were* able to answer some questions regarding the mention of lead shielding in some of the transfer records, verifying that the lead listed was a shipping container and that it was not buried at the RWMC.

The data in Bartolomucci (1989) had already been factored into the RWMIS database; RWMIS was checked against that letter to make certain that the database was current, at least regarding the changes brought about by the letter. The radionuclide distribution numbers from the letter were also used because Bettis/NRF would have the most detailed information concerning what materials went into the core structurals. After Nieslanik (1994) became available, it was used to refine the data pertaining to scrap cask shipments before 1976.

Description of Waste Streams. The NRF waste was divided into 11 waste streams (see Table 2-14). The five most important waste streams from NRF are discussed in detail below.

As stated previously, the majority of the radioactivity from NRF came from ECF in scrap cask inserts. Four NRF waste streams encompass this waste: NRF-618-2H (1955–1975), NRF-618-3H (1976–1980), NRF-618-4H (1981–1983), and NRF-618-5H (1955–1975). The waste was divided into these four streams based on the three indicated sequential time periods because of changes in radionuclide distribution within the waste streams. The fourth stream, NRF-618-5H, was included because the zirconium also was shipped out in the scrap casks. For each of the five streams, the discussion tells how the stream was generated, the principal contaminants in the stream, the specific information sources reviewed and used, and the assumptions and analyses used to estimate the quantities of the contaminants.

NRF-618-2H (Naval core structural scrap, 1955–1975)

- **Genèration of the waste stream.** Structural material was cut from naval fuel before the fuel elements were sent to ICPP for reprocessing. This waste stream, as well as NRF-618-3H and NRF-618-4H, consisted of this irradiated structural material, mostly stainless steel, with some inconel and zircaloy. The scrap material was highly radioactive; it was shipped to the RWMC in shielded scrap casks and remotely handled. This stream included shipments from 1955 through 1975.

- **Principal radiological contaminants.** Starting with the nuclide with the greatest activity, the principal radionuclides in this waste stream are Co-60, Fe-55, Ni-63, Sb-125, and Sn-119m.

Table 2-14. Waste streams originating at the Naval Reactors Facility.

Waste stream number	Description of waste
NRF-601-1H	Low-level compactible and noncompactible waste from operation of the S1W reactor and related activities
NRF-617-1H	Low-level compactible and noncompactible waste resulting from operation of the A1W reactors and related activities
NRF-617-2H	Lead and asbestos
NRF-618-1H	Dissolved pressurized water reactor fuel rods absorbed in vermiculite
NRF-618-2H	Structural components from Navy core fuel bundles; end boxes and other components—1955–1975
NRF-618-3H	Structural components from Navy core fuel bundles; end boxes and other components—1976–1980
NRF-618-4H	Structural components from Navy core fuel bundles; end boxes and other components—1981–1983
NRF-618-5H	Zirconium alloy (zircaloy) cladding from Navy cores
NRF-618-6H	Solidified sludge, resin, waste liquids in vermiculite
NRF-618-7H	Low-level compactible and noncompactible waste resulting from work at ECF water pits and hot cells
NRF-633-1H	Low-level compactible and noncompactible waste resulting from operation of the S5G reactor

- **Information sources reviewed and used.** The above radionuclide distribution was taken from Nieslanik (1994). Several inventory reports were reviewed, but no additional information on this stream was located.

- **Assumptions and analysis.** An assumption was made that the variations in radionuclide content in the scrap at various time periods from 1955 through 1975 were unimportant and that the scrap could be considered to be generally homogeneous. The data presented in Nieslanik (1994) were accepted as being the most reliable currently available.

NRF-618-3H (Naval core structural scrap, 1976–1980)

- **Generation of the waste stream.** The same process generated this stream as generated NRF-618-2H; the time period is 1976 through 1980.

- **Principal radiological contaminants.** The principal radionuclides in this waste stream are Fe-55, Co-60, Sb-125, Zr-95, Sn-119m, and Ni-63.

- **Information sources reviewed and used.** Data were taken from RWMIS as amended by Bartolomucci (1989).

- **Assumptions and analysis.** The data presented in Bartolomucci (1989) were accepted as being the most reliable currently available.

NRF-618-4H (Naval core structural scrap, 1981–1983)

- **Generation of the waste stream.** The same process generated this stream as generated NRF-618-2H; the time period is 1981 through 1983.

- **Principal radiological contaminants.** The principal radionuclides in this waste stream are Ni-63, Co-60, Fe-55, and Co-58.

- **Information sources reviewed and used.** The data were taken from RWMIS, as amended by Bartolomucci (1989).

- **Assumptions and analysis.** The data presented in Bartolomucci (1989) were accepted as being the most reliable currently available.

NRF-618-5H (Zirconium alloy scrap)

- **Generation of the waste stream.** This waste stream was generated by the same process as waste streams NRF-618-2H, NRF-618-3H, and NRF-618-4H. Structural material was cut from naval cores before the fuel elements were sent to ICPP for reprocessing. This stream consisted of zirconium alloy (zircaloy) cladding and fuel element end pieces. This material, generated during cutting and milling operations on the fuel elements in the ECF water pits, was collected from the bottom of the ECF water pits and placed into 5-gal cans; the cans were loaded into a scrap cask insert for transfer to the RWMC. These shipments

were handled differently from other scrap shipments because of the need to keep the zirconium covered with water until it was buried under soil. The objective was to prevent fires in the pyrophoric zirconium fines.

- **Principal contaminants.** The contaminant of interest in this waste stream is zircaloy. This material contains a principal radiological contaminant, Zr-95, as well as a principal nonradiological contaminant, zirconium. The zirconium is considered a hazard because of its pyrophoric nature.

- **Information sources reviewed and used.** Information on the number, volume, and weight of zircaloy shipments was obtained from RWMIS and from the individual original waste transfer records. Several inventory reports were reviewed, but no additional information on this stream was located. Zirconium activity was taken from Bartolomucci (1989) and Nieslanik (1994).

- **Assumptions and analyses.** Estimates of the weight of zirconium in given shipments were obtained from 1965 waste transfer forms. From these data, an average weight was determined for zirconium shipments. This average was then applied to earlier shipments for which such information was not given. In this way, an estimate was made for the total weight and activity of zirconium transferred to the RWMC from ECF.

NRF-618-7H (ECF compactible and noncompactible waste)

- **Generation of the waste stream.** Operation of a fuel examination facility such as ECF involves the handling of highly radioactive materials, both in the water pits and in the hot cells. Daily operations create large quantities of rags, plastic, blotter paper, rubber gloves, and other materials that become contaminated with radionuclides when used to limit the spread of radioactive contamination. Noncompactible items such as sections of contaminated ventilation ducts, piping, valves, tools, and glassware, are frequently packed with the compactible component of the waste stream. The radioactive material in this waste stream is in particulate form. This material is enclosed in plastic bags, and the bags are then packed into cardboard boxes for transfer.

- **Principal radiological contaminants.** The principal radionuclides in this waste stream are Co-60, Fe-55, and Ni-63.

- **Information sources reviewed and used.** This information was taken from Nieslanik (1994).

- **Assumptions and analysis.** The curie content contained in waste streams NRF-618-1H through NRF-618-6H, as listed in RWMIS, was verified by comparison with original transfer forms. The summed activity in curies in these six streams was then subtracted from the total activity listed in RWMIS for ECF, and the balance was assumed to be the activity contained in the ECF compactible and noncompactible waste stream. A second assumption was made that the distribution of radionuclides in the ECF compactible and noncompactible waste was constant over the period of time studied (1960 through 1983), and was given by Nieslanik (1994).

2.4.5 Argonne National Laboratory-West

The Generator. ANL-W is located in the southeastern part of the INEL, approximately 56 km (35 mi) west of Idaho Falls (see Figure 2-1).

Since the beginning of operation, the mission of ANL-W has been the research and development of liquid metal-cooled reactors and advanced nuclear power plant technology. The primary focus for ANL-W research until 1994 was the Integral Fast Reactor (IFR) Project integrated with an onsite fuel recycling process called pyroprocessing. The objectives were to increase reactor safety, reduce radioactive waste components and concentrations, and improve reactor fuel efficiency.

ANL-W consists of seven major complexes: (1) the EBR-II, (2) the Transient Reactor Test Facility (TREAT), (3) the Zero Power Physics Reactor (ZPPR), (4) the Hot Fuel Examination Facility (HFEF), (5) the Fuel Cycle Facility (FCF), (6) the Fuel Manufacturing Facility (FMF), and (7) the Laboratory and Office (L&O) Building and support facilities such as the Radioactive Liquid Waste Treatment Facility (RLWTF), the Sodium Components Maintenance Shop (SCMS), and the Sodium Process Facility (SPF).

EBR-II consists of a sodium-cooled reactor with a thermal power rating of 62.5 MW, an intermediate closed loop of secondary sodium, and a steam plant that produces 19 MW of electrical power through a conventional turbine generator. The original emphasis in the design and operation of EBR-II was to demonstrate a complete breeder reactor power plant with onsite reprocessing of metallic fuel. The demonstration was successfully carried out from 1964 to 1969. The emphasis at EBR-II was then shifted to irradiation testing of fuels and materials for future, larger liquid metal reactors. The EBR-II has also been used to provide electrical power for ANL-W and the INEL. The EBR-II cooling tower, SCMS, and SPF are also associated with EBR-II. The SCMS facility is used to remove sodium from reactor components for repair or replacement.

The TREAT reactor is an uranium oxide-fueled, graphite-moderated, air-cooled reactor. It was designed to produce short, controlled bursts of nuclear energy to simulate accident conditions leading to nuclear fuel damage. The reactor became operational in 1959. Tests at TREAT provide data on fuel cladding damage, fuel motion, coolant channel blockages, molten fuel/coolant interactions, and potential explosive forces during an accident.

ZPPR is the national facility for testing the physics properties of advanced, fast-spectrum reactors. ZPPR is designed to study the properties of experimental reactor cores. Experimental cores are built by hand-loading plates of reactor materials into drawers, which are then put into the designed pattern. The designs are tested at low power levels to determine characteristics of the core.

FCF (formerly called HFEF/S) became operational in 1964 and was used to demonstrate pyrometallurgical fuel reprocessing for EBR-II fuel during the first few years of operation. In that mode of operation, a remotely operated production line was used for processing and refabricating spent EBR-II fuel and returning it to the reactor. After successfully demonstrating this process in 1969, this mission was discontinued, and the facility was used to examine irradiated fuels and material experiments from EBR-II and TREAT and to provide other reactor support services such as spent fuel transfer to ICPP. FCF consists of two hot cells: one with an air atmosphere and the other with an inert argon-gas atmosphere. There are 23 hot cell work stations around the outside perimeter of the

FCF hot cells and 4 active work stations in the center work space of the argon cell. FCF is now being modified for use in demonstrating new remote recycling and refabrication fuel cycle processes for DOE. The facility has been upgraded and reequipped with new process equipment to carry out this demonstration.

HFEF (formerly HFEF/N) went into operation in 1975 and is used for examining irradiation experiments. Examinations conducted in the HFEF provide data that are essential for determining the performance and conditions of fuels and materials irradiated in the EBR-II reactor, the TREAT reactor, and other DOE reactor facilities. HFEF consists of two shielded hot cells: the decontamination cell, which contains an air atmosphere, and the main cell, which contains an argon gas atmosphere. Each of the 21 work stations in HFEF is equipped with shielded windows and master/slave manipulators. The main cell is used for work involving exposure of materials such as sodium, plutonium, and other materials that would react chemically with air.

The FMF contains the entire operation for the manufacturing of metallic fuel elements within a single building. The building contains a casting furnace and large gloveboxes for encapsulating and bonding the cast fuel slugs in a stainless-steel jacket.

Within the L&O Building is the analytical laboratory, which consists of hot cells, chemistry laboratories, and the Experimental Fuels Laboratory (EFL). The analytical laboratory provides chemistry support for ANL-W in the areas of environmental compliance, fuel chemistry, sodium/water chemistry, and waste classification analysis. The EFL is used in the development and fabrication of prototype metallic nuclear fuels.

The RLWTF receives low-level radioactive liquid waste from ANL-W facilities and stores the waste in storage tanks before evaporation in the shielded hot air drum evaporators. The L&O Building, FCF, and HFEF pipe liquid waste to the RLWTF facility directly. The RLWTF began operating in June 1983. Before June 1983, the low-level liquid evaporation process took place in the basement of the L&O Building.

Generation of the Waste. Solid radioactive waste generated at ANL-W was primarily associated with irradiated experimental fuel subassemblies and capsules from EBR-II and, to a lesser degree, TREAT. (*The term "experimental fuel" does not include spent EBR-II driver fuel, which was historically shipped to ICPP. "Spent nuclear fuel," as defined in DOE Order 5820.2A, was not stored or processed at ANL-W during the time period covered by this report.*) After irradiation in ANL-W reactors, the subassemblies and capsules were conveyed to appropriate facilities for dismantling, sampling, and examination. If they were not contaminated with sodium (the coolant used in EBR-II), these reactor pieces and parts were shipped to the RWMC as remote-handled waste. Sodium-contaminated reactor parts were stored in the Radioactive Scrap and Waste Facility (RSWF) at ANL-W.

Various types of radioactive waste were generated during routine reactor and hot cell operations, maintenance activities, and cleanup and decontamination processes at ANL-W. Examples of ways in which various types of waste were generated include

- **Dry active waste.** Generated routinely in general plant operation, maintenance, decontamination, and monitoring activities. Major generators of ANL-W dry active waste were EBR-II, TREAT, HFEF, FCF, and the analytical laboratory.

- **Hot cell waste.** Generated from hot cell operations at FCF and HFEF. Most of this waste stream was stored in the RSWF, but some was sent to the RWMC.

- **Junior caves waste.** Generated from operations of the ANL-W hot cells.

- **Nonstandard waste forms.** Out-of-the-ordinary waste types (usually large pieces of excess or demolished equipment) nonroutinely shipped to the RWMC. This type of waste was shipped from all ANL-W radiological control areas.

- **Concreted evaporator bottoms.** Radioactive liquids were received and evaporated at the central liquids processing area in the basement of the analytical laboratory. Generators of the liquids were FCF, HFEF, and TREAT.

General Availability of Information. Most ANL-W waste information was found in library and archival storage at the INEL or was retrieved from the Federal Records Center in Seattle, Washington. Information included old waste shipment records, printouts from RWMIS, personal interviews with long-time employees, National Environmental Policy Act documents, miscellaneous reports (some in draft versions), technical studies, and correspondence.

Historical data analyzed were sufficient to verify total waste volumes shipped to the RWMC. Waste volumes reported in RWMIS were usually verified in the various studies and reports. Also, the information reported over the years 1962 to 1983 usually differentiated various waste types adequately (e.g., remote-handled versus contact-handled or "dry active waste" versus reactor components). To this extent, the data are reliable. However, the data, especially from the 1960s and 1970s, were usually vague in providing radionuclide information. Occasionally, specific radionuclides were reported in the waste shipment records. However, radionuclides were usually reported only as MAP and/or MFP in the early years (1962 through 1972).

In the 1960s, the reported radioactivity in waste shipments was only a gross calculation based on radiation readings from the waste packages. The same formula was used to calculate radioactivity for many container types; thus, the radioactivity determinations for the period are suspect.

Beginning about 1971, improved algorithms were used to quantify total radioactivity from radiation readings. Formulae were developed for different container types. The revised algorithms gave better indications of the actual amounts of radioactivity contained in the waste shipments to the RWMC.

Conservative generalizations were made about ANL-W radionuclide distributions for instances in which the contaminants were listed as MAP, MFP, or unidentified beta-gamma. A previous study based on RWMIS records (Plansky and Hoiland 1992) suggested a generic radionuclide profile for ANL-W LLW sent to the burial grounds since 1961. This generic profile listed Sr-90 as one of the constituents. More recent studies (Grant 1992; Nielsen 1993) propose an even greater presence of Sr-90 in ANL-W waste streams, taken as a whole, than that suggested by Plansky and Hoiland. In

addition, subassembly hardware contains Cr-51, which was not identified by Plansky and Hoiland in the ANL-W MAP. The ANL-W radionuclide distribution used here for generic entries is as follows:

- MAP: 55% Co-60, 20% Cr-51, 15% Mn-54, and 10% Co-58
- MFP and unidentified beta/gamma-emitters: 50% Sr-90, 30% Cs-137, and 20% Ce-144
- No appreciable amount of radioactivity from ANL-W was listed as unidentified alpha.

ANL-W waste information gave few details about nonradiological contaminants in shipments to the RWMC. Some clues were given in some waste descriptions (e.g., source storage pig, lead pipe, and thermometer) in RWMIS and shipping records. In a study performed in 1987, ANL-W facilities estimated their historical use of chlorinated solvents. When found, such information (e.g., Pohto 1980) about nonradiological contaminants is listed on the appropriate waste stream data forms.

Data-Collection Approach. ANL-W Records Management archives were searched for information germane to the study. Most pertinent shipping records and health physics logs for the time period (1962 to 1983) had been sent to the Federal Records Center in Seattle. The records were retrieved and examined. Other ANL-W archival storage areas were searched.

Some reports on ANL-W waste management and the ANL-W section of the INEL Environmental Impact Statement (ERDA 1977) were found and used. Also, more recent analyses of ANL-W waste were used (e.g., Grant 1992; Nielson 1993). RWMIS was used in the absence of other data.

Description of Waste Streams. The ANL-W waste is divided into eight waste streams (see Table 2-15). The four most important waste streams are discussed in detail below. For each of these streams, the discussion tells how the stream was generated, the principal contaminants in the stream, the specific information sources reviewed and used, and the assumptions and analysis used to estimate the quantities of the contaminants.

ANL-752-3H (Concreted evaporator bottoms)

- **Generation of the waste stream.** This waste stream consisted of liquid radioactive waste from FCF (the principal generator), HFEF, and the L&O Building. The liquid was processed through a steam-heated tube bundle. About 1,500 gal of liquid was evaporated down to 15 gal of viscous liquid. Initially, the resulting liquid was divided into two 7.5-gal portions. Each portion was placed into a container, which was then encapsulated in a concrete-lined, 55-gal drum. Because of the high radiation fields associated with the concentrated liquids, the process was modified in 1974. After modifications, the concentrated liquid waste stream was directed into shielded hot drum evaporators (15-gal drums encased in concrete).
- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Co-60 and Cs-137.
- **Information sources reviewed and used.** Shipping records from the study period were used to identify the volumes and radioactivity of waste disposed of. Correspondence and files with documents describing the use of the evaporator system were also used. In

Table 2-15. Waste streams originating at Argonne National Laboratory-West.

Waste stream number	Description of waste
ANL-752-1H	Dry active waste routinely generated in facility monitoring, operations, and maintenance activities; laboratory and sample waste
ANL-752-2H	Combustibles (paper, cloth, etc.); plastic; metal; and filters
ANL-752-3H	Concreted evaporator bottoms
ANL-765-1H	Dry active waste routinely generated in facility monitoring, operations, and maintenance activities
ANL-765-2H	Subassembly hardware (from nuclear fuel and material experiments), gloves, coveralls, plastic, and building materials
ANL-767-1H	Dry active waste routinely generated in facility monitoring, operations, and maintenance activities
ANL-785-1H	Subassembly hardware (from nuclear fuel and material experiments), rags, plastic sheeting, and equipment
ANL-EBRI-1H	A wide range of waste from EBR-I

addition, information was obtained through interviews with health physics personnel who worked in the area during the years of operation.

- **Assumptions and analysis.** Shipping records of the evaporator bottoms waste characterized the waste to be 90% MFP. This characterization was retained, with the remaining 10% assumed to be MAP. No uranium or transuranium radionuclides were assumed to be contained in the waste. The most likely concentrated heavy metals in the liquids are cadmium and chromium.

ANL-765-1H (FCF dry active waste—combustibles, filters, metals)

- **Generation of the waste stream.** This waste stream was generated during routine reactor operations, maintenance procedures, and cleanup and decontamination processes. Solids in this waste include paper, plastic, rubber, wood, metal pieces, and floor sweepings.

- **Principal nonradiological contaminants.** The principal nonradiological contaminant in this waste stream is lead.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Mn-54, Co-58, Co-60, Sr-90, Cs-137, and Ce-144.

- **Information sources reviewed and used.** Documents by Witbeck and Fryer (1979) and ANL-W (1973) were used, along with shipping records.

- **Assumptions and analysis.** The staging area for this waste stream, the truck lock building (ANL-765) was also the accumulation area for waste from other ANL-W buildings, especially after 1972. Although radionuclide distributions probably varied somewhat from building to building, the relative percentages of radionuclides were assumed to be constant throughout the waste stream. Radioactivity amounts reported by the information sources were almost always obtained by radiation readings on waste containers. Finally, personnel over the years reported the radioactivity to be principally MFP, so it was assumed that only 10% of the radioactive contaminants were MAP.

ANL-765-2H (FCF hot cell waste—principally subassembly hardware)

- **Generation of the waste stream.** This waste was generated during routine operations of hot cells. The waste was primarily subassembly hardware and other highly irradiated metal pieces. The waste also included a significant amount (approximately 25%) of dry active waste-type materials.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Mn-54, Co-58, Co-60, Sr-90, Cs-137, Cr-51, and Ce-144.

- **Information sources reviewed and used.** Documents by Witbeck and Fryer (1979) and ANL-W (1973) were used, along with shipping records.

- **Assumptions and analysis.** The relative percentages of radionuclides were assumed to be constant throughout the waste stream. Activities reported by the information sources were often obtained by radiation readings on waste containers. Sometimes, radionuclide profiles of hot cell waste were determined by analyses of smears. It is known from smear analysis that the radioactivity was mostly from MAP (70%). The remainder was assumed to be from the MFP radionuclides listed above.

ANL-785-1H (HFEF hot cell waste—principally subassembly hardware)

- **Generation of the waste stream.** This waste was generated during routine operations of hot cells. The waste was primarily subassembly hardware and other highly irradiated metal pieces. The waste also included dry active waste-type materials.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Mn-54, Co-58, Co-60, Cr-51, Sr-90, Cs-137, and Ce-144.

- **Information sources reviewed and used.** Documents by Witbeck and Fryer (1979) and ANL-W (1973) were used, along with shipping records.

- **Assumptions and analysis.** The relative percentages of radionuclides were assumed to be constant throughout the waste stream. Activities reported by the information sources were often obtained by radiation readings on waste containers. Radionuclide profiles of hot cell waste sometimes were determined by analyses of smears. It is known from smear analysis that the radioactivity was mostly from MAP (70%). The remainder was assumed to be from the MFP radionuclides listed above.

2.4.6 Rocky Flats Plant

The Generator. The RFP is located west of Denver, Colorado, and north of Golden, Colorado. It was one of DOE's nuclear weapons production facilities, but it recently ceased production activities. The RFP used specialized machine shops to process raw nuclear material into the finished components required by the warhead designs. Plutonium and beryllium components were fabricated into the shells of fissionable materials, called pits. Presently, the RFP mission is to disassemble the pits from retired weapons. The recovered plutonium is chemically processed to remove americium. Plutonium scrap recovery is also performed at the RFP.

Before 1960, the main plutonium purification process was dissolution followed by a solvent extraction step that used tributylphosphate as the solvent and dodecane as the diluent. The solvent extraction step was followed by cation exchange. Around 1960, solvent extraction was eliminated from the recovery process because the materials going through the process were becoming more and more varied and could not be adequately handled by the process. The solvent extraction process was replaced by dissolution in nitric acid followed by ion exchange and peroxide precipitation. The purified plutonium oxide was converted to plutonium fluoride and reduced to plutonium metal using calcium (ChemRisk 1992a). Other chemical processes, such as molten salt extraction, have also been used at the RFP.

A need to process americium arose because of a personnel exposure problem from its gamma ray emissions. From late 1957 until the late 1970s, americium was recovered and purified at the plant for resale. The demand for americium dropped off in the late 1970s, and the americium was processed as waste (ChemRisk 1992a).

Depleted uranium operations were a significant part of the original manufacturing performed at the plant. Operations included casting, machining, rolling, and forming. Alloying of depleted uranium with niobium began in 1966, although full-scale production did not occur until the early 1970s (ChemRisk 1992a). Depleted uranium, which contains less than 0.7% U-235 by mass, is rich in the U-238 radionuclide. The RFP depleted uranium is assumed to be material type U-12, which is comprised of 99.78% U-238, 0.215% U-235, 0.006% U-236, and 0.001% U-234 by mass according to the *Solid Waste Information Management System (SWIMS) Users Manual* (EG&G Idaho 1985a).

Enriched uranium, containing about 93% U-235 by mass, was processed at the RFP from 1952 to 1964. This concentration of U-235 is material type U-38, which is comprised of 93.08% U-235, 5.65% U-238, 0.93% U-234, and 0.34% U-236 by mass, according to EG&G Idaho (1985a). The

enriched uranium manufacturing processes included casting, forming, machining, assembly, recovery, and purification.

The enriched uranium chemical recovery line began operations in 1954. The chemical recovery used a solvent extraction process with dibutylethylcarbutol as the solvent and dodecane as the diluent. This process was similar to the early solvent extraction process used for plutonium recovery. A solvent still was operated at the plant, and some of the distilled solvent was reused. The discarded solvent and oils were drummed and later became part of the organic sludge waste stream. Enriched uranium operations were shut down in 1962 and left the plant in 1964 (ChemRisk 1992a).

Some U-233 was processed from the late 1950s to the early 1970s. The U-233 processing included casting, machining, aqueous processing, and separations (ChemRisk 1992a). Records indicate that the INEL received 56 g of U-233 as waste from the RFP in 1967 (Lee 1971). No details are currently available on this waste.

Generation of the Waste. All of the plutonium operations are carried out in enclosures that are operated under subatmospheric pressure to minimize uncontrolled releases of radioactive material into the operating area. These enclosures are called gloveboxes, and their ventilation systems pass through a high-efficiency particulate air (HEPA) filter system. Leaded rubber gloves are used to protect operations personnel from the gamma activity associated with the plutonium and americium.

The filters from the ventilation systems and the filters used in other systems eventually become waste. The leaded rubber becomes contaminated and also becomes waste. Some of the processes used produce liquid waste streams. These liquid streams are converted to a sludge or solid with adsorbents or cements. Contaminated equipment, clothing, and tools end up as radioactive waste. Waste is also generated by decontamination projects and modifications to facilities.

All radioactive waste from the RFP that was sent to the INEL from 1954 to 1970 was buried at the RWMC. Transuranic waste received after October 1970 has been stored aboveground at the TSA (Card 1977). Uranium waste from the RFP was received and buried at the RWMC through 1972. The uranium waste was not part of any of the plutonium waste streams. The plutonium waste contains varying amounts of americium, depending on the part of the process where the waste originated.

Thousands of small-scale releases and accidents were identified by the 1992 ChemRisk study. Many of the widely reported historical events are described in the ChemRisk (1992a, 1992b) reports. Some of these events, such as the 1957 fire in Building 771 and the 1969 fire in Buildings 776 and 777, slowed down or stopped waste generation by some parts of the manufacturing or recovery processes. However, waste generation was increased in the areas connected with cleanup after the accidents. Any changes in the amount of waste generated in a particular waste stream because of any of these accidents was not tracked. Any changed amount in the total volume of waste shipped each year (Lee 1971) because of a particular event is not available.

General Availability of Information. The information available on RFP waste buried at the RWMC is quite general. Tables I and II of a letter from the RFP (Lee 1971) provide an estimate of the volume of waste and the amount of plutonium, americium, and uranium radionuclides shipped annually to the RWMC from 1954 to 1970. Until now, this was the best available information on

RFP waste buried at the RWMC, but the reliability of the information on the activities of the radionuclides has long been questioned (e.g., Darnell 1981).

Recent information (Appendix C) based on RFP-wide mass balances has provided current best estimates of the total amount of plutonium, Am-241, and enriched uranium that was buried at the RWMC from 1954 to 1972. (TRU waste was not buried after 1970.) However, this information does not supply data on the nonradiological contaminants or the physical or chemical forms. No other documents are known that would supply this information on the buried waste from the RFP. Although some of the buried waste was retrieved in the Initial Drum Retrieval Program (McKinley and McKinney 1978) and the Early Waste Retrieval Program (Bishoff and Hudson 1979), the hazardous nature of the waste severely limited the information gained about its characteristics.

More specific information is available on the stored TRU waste received after 1970 from the RFP. The TRU waste information is related to RFP content codes, which differ from the RWMIS content codes. Examples of the information available on the stored RFP waste content codes are

- Average amount of plutonium and americium per waste container (Clements 1982)
- Average weight of each waste container (Clements 1982)
- Waste description, including how and where it was generated and how it was packaged (Clements 1982)
- Types and estimated quantities of nonradiological contaminants per container (Kudera 1989).

Data-Collection Approach. Because of the general lack of information (other than the amounts of plutonium, Am-241, and uranium) on the buried waste from the RFP, a unique approach was developed to provide estimates of the quantities of nonradiological contaminants and the physical and chemical form of all the contaminants. The approach is described below and is more complex than the approach used for the other generators.

A detailed description of how the stored waste was generated and packaged is available and allows a reasonable estimate of the physical and chemical form of the waste and the radiological and nonradiological contaminants. However, for the information on the RFP content codes to be useful as buried waste information, it must be related to how much of each RFP content code was buried. Therefore, the data-collection approach chosen involves adapting information on the stored waste to represent the corresponding parameters of the buried waste. Although the RFP grew in physical size over the years, the nature of the processes and the general types of materials used in these processes have remained largely the same since the 1950s (ChemRisk 1992a).

Information on 39 RFP-stored waste content codes that can be used to represent the RFP waste buried at the RWMC was assembled and entered into a separate database. The information on these stored waste content codes was combined, for similar content codes, into 14 buried waste streams. This combination of content codes into waste streams is based on the recommended waste form classifications at the INEL (Clements 1991). The content codes were combined as shown in Table 2-16.

Table 2-16. Combination of Rocky Flats Plant stored waste content codes to form plutonium buried waste streams.

Buried waste stream	Content codes for RFP stored waste
Benelex, plexiglas	464
Cemented sludges	004
Uncemented sludges	001, 002, 290
Combustibles	330, 336, 337, 900, 970
Concrete, brick	371, 960
Filters	335, 338, 360, 490
Glass	440, 441–442[a]
Glovebox gloves	463
Metals	320, 480, 481
Mixed waste[b]	950
Nonmetal molds and crucibles	300, 301, 370
Particulate waste	310, 311, 374, 375, 391, 393, 420, 421, 422, 425
Resins	430
Salts	410, 411

a. Content codes 441 and 442 have been combined on one data sheet.

b. This stream is a mixture of some of the other buried waste streams, such as combustibles, metals, and glass. The term is not used here in the usual sense of describing waste that is regulated under the Atomic Energy Act and RCRA.

The extrapolation of the stored waste data to make it apply to the 14 buried waste streams required a series of calculations. Table 2-17 summarizes the calculations used and helps describe the calculations. The letter designations from the blocks in Table 2-17 are included in the following descriptions for clarity.

When the stored waste content codes were combined to form the 14 buried waste streams, it was necessary to generate the following information:

- **B.a.** The total annual quantity "disposed of" for each hazardous chemical and each radionuclide in all of the plutonium-stored waste content codes that were combined to one waste stream.

- **B.b.** The ratio of the quantity of each hazardous chemical to the quantity of plutonium in each combined waste stream. This was obtained by dividing the quantity of each hazardous chemical derived in B.a. by the quantity of plutonium derived in B.a.

Table 2-17. Summary of calculations to convert Rocky Flats Plant stored waste data to buried waste data before 1970.

A. Stored waste content codes (CC) (after 1970)		B. Buried waste streams (BWSs) (1–14) (after 1970)		C. Buried waste streams (BWSs) (1–14) (before 1971)	D. Uranium buried waste streams (before 1973)
A.a. Sum the annual quantity "disposed of" for each hazardous chemical or each radionuclide (Part C or D of the data form) for each CC to be combined	——>	**B.a.** Quantity of each hazardous chemical or radionuclide in each BWS (after 1970)		**C.a.** Estimate of total plutonium and americium buried at the RWMC (Appendix C) (before 1971)	**D.a.** Total quantity of depleted uranium buried at the RWMC (Lee 1971; Litteer 1988) (before 1973)
		B.a.Pu. Quantity of plutonium in each BWS (after 1970)	C.a. × B.d. =	**C.b.** Total amount of RFP plutonium in each BWS (before 1971)	**D.b.** Estimate of total enriched uranium buried at the RWMC (Appendix C) (before 1973)
		B.a.Haz Chem Quantity of each hazardous chemical in each BWS (after 1970)	C.b. × B.b. =	**C.c.** Total amount of each hazardous chemical in each BWS (before 1971)	**D.c.** Estimate of total U-233 buried at the RWMC (Lee 1971) (before 1973)
	$\frac{\text{B.a.HazChem}}{\text{B.a.Pu}}$ =	**B.b.** Ratio of each hazardous chemical to plutonium in each BWS (after 1970)	Σ_{1}^{14} C.c. =	**C.d.** Sum of the quantities of each hazardous chemical in all of the BWSs (before 1971)	
	Σ_{1}^{14} B.a.Pu =	**B.c.** Sum of the quantities of plutonium in all of the BWSs (1–14) (after 1970)			
	B.a.Pu/B.c. =	**B.d.** Fraction of plutonium in each BWS (after 1970)			

To extrapolate the stored waste data to the waste that is buried at the RWMC, a plutonium percent of each of the combined waste streams must be obtained (B.d.). This was calculated by dividing the total average annual quantity of plutonium "disposed of" for a buried waste stream (B.a.Pu) by the combined average annual quantity of plutonium "disposed of" for all waste streams (B.c.). This provided the average plutonium percent of a buried waste stream expressed as a decimal fraction. This calculation was performed for each buried waste stream. The total of the average plutonium percents for all 14 buried waste streams is 100%.

The extrapolation was then made by multiplying the average percent, as a decimal fraction, B.d., of each waste stream by the estimate of the total quantity of plutonium shipped from the RFP before 1971 (C.a.). This provided the total amount of plutonium in each waste stream shipped to the RWMC before 1971 (C.b.). For information, the best estimate of the total amount of plutonium, americium, and enriched uranium (predominantly U-235) buried at the RWMC (from Appendix C) is shown in Table 2-18 in terms of kilograms.

The total quantity of each hazardous chemical for each buried waste stream before 1971 (C.c.) was obtained by multiplying the total amount of plutonium in each buried waste stream (C.b.) by the ratio of the quantity of each hazardous chemical to the quantity of plutonium in each combined waste stream (B.b.). The quantity of each hazardous chemical in all of the buried waste streams (C.d.) was obtained by calculating the total of all of the quantities derived in C.c.

For two other plutonium buried waste streams, sufficient information was available to characterize the streams directly, rather than by using the indirect method just described. These streams are discussed below. In addition, three uranium buried waste streams do not contain any data on nonradiological constituents because of a lack of information. Finally, a nonplutonium-nonuranium waste stream, consisting of a few drums containing radiation sources, is discussed.

Organic Sludge—Organic chemicals used as degreasing agents and for other processes were stored at the RFP for several years because there was no method for processing them into an acceptable waste form. A process to convert the organic chemicals into a sludge was developed. The first drums of this content code, 003 Organic Sludge, were shipped to the RWMC in 1966. The backlog of stored organic chemicals was processed and shipped to the RWMC over the next 3 years. This has been a continuous waste stream since that time.

Table 2-18. Best estimates and upper bounds of Rocky Flats Plant plutonium, americium, and enriched uranium (mass at time of disposal) buried at the Radioactive Waste Management Complex.

Radionuclide	Best estimate (kg)	Upper bound (kg)
Plutonium	1,102	1,455
Am-241	44	58
Enriched uranium	386	603

Detailed annual data were available on this waste stream. The waste stream was buried at the RWMC only from 1966 through October 1970. Therefore, it was decided to enter the data directly as a buried waste stream; the above extrapolation technique does not apply to this waste. This approach artificially increases, slightly, the total amount of plutonium that is estimated to have been buried (Appendix C). However, the amount of the difference is very small compared with the total amount of plutonium shipped from the RFP to the RWMC.

Evaporator Salts—Liquid effluents from the second stage of treatment of aqueous process waste and all other plant-generated liquid waste not requiring treatment were concentrated in solar evaporation ponds. The liquid was then pumped from the ponds to an evaporator, concentrated, and dried to form a salt residue. The salt residue was packaged in 55-gal drums. The first drums of this evaporator salt, content code 005, were shipped to the RWMC in 1967. This waste was not considered TRU waste because the concentration of the TRU radionuclides was normally less than 10 nCi/g. It was buried through 1972. This evaporator salt waste was then placed on Pad A through 1978, when its shipment to the INEL was halted. The Pad A waste is addressed here as if it were from a separate waste generator and is included in the data for this report. Therefore, these salt waste data cover only the years from 1967 through 1972.

As discussed in Section 2.4.8, the waste disposed of on Pad A (which received waste from 1972 through 1978) was addressed separately from the other waste disposed of in the HDT, regardless of the generator that produced the Pad A waste.

Specific data on the number of evaporator salt drums received from 1967 through 1970 are available in a letter from T. L. Clements to J. D. McKinney (Clements 1980a). The evaporator salt drums received in 1971 and 1972 were buried in Pits 11 and 12. The number of evaporator salt drums in these pits is available in the *Initial Drum Retrieval Final Report* (McKinley and McKinney 1978). Specific details on the composition of the salt waste were taken from the Clements (1982) report. Some additional information on the composition of the salt waste was obtained from a Pad A report (Halford et al. 1993). This information was combined and reported as a buried waste stream.

Uranium Waste Streams—There are three uranium waste streams: the depleted uranium waste stream, the enriched uranium waste stream, and the U-233 waste stream.

The quantity of depleted uranium (primarily U-238 by mass) that was shipped from the RFP to the RWMC from 1954 through 1970 was obtained from Table II of the RFP letter of 1971 (Lee 1971). Detailed characteristics of this depleted uranium waste stream are not available. The RWMIS database (Litteer 1988) indicates that the RFP sent waste containing depleted uranium to the RWMC until 1972. The depleted uranium data from RWMIS were used for 1971 and 1972. This total for depleted uranium is the quantity derived in D.a. of Table 2-17.

The best estimate of the total amount of enriched uranium buried from 1954 to 1972 was obtained from Appendix C and is shown in Table 2-18. This total is the quantity represented by D.b. in Table 2-17. Detailed characteristics are not available.

The best estimate of the total amount of U-233 (which was received only in 1967) was obtained from Lee (1971). This total is the quantity represented by D.c. in Table 2-17. Detailed characteristics are not available.

Radiation Sources Waste Stream—Between 1965 and October 1970, the RFP shipped 31 radiation sources to the INEL for burial. The information on shipment of these radiation sources was taken from an engineering design file (Clements and Darnell 1994) that documented the shipments form 1965 through 1979. Most of these radiation sources were shipped in drums of other RFP waste streams. Therefore, this stream does not add any volume to that buried in the SDA. The total activity of the radionuclides in this waste stream is very small compared with the totals buried in the SDA. The radiation sources disposed of in the SDA from the RFP are Co-60, Cs-137, H-3, radium/beryllium neutron sources, and Ra-226 from gauges. These radiation sources also contribute some lead and beryllium to the nonradiological contaminants shipped from the RFP to the INEL.

Description of Waste Streams. With the addition of the organic sludge, evaporator salts, three uranium streams, and a radiation sources stream, there are 20 buried waste streams from the RFP. Table 2-19 provides a list of all of the buried waste streams.

The 13 most important waste streams from the RFP are discussed in detail below. Each of the following waste stream summaries describes how the stream was generated and the principal radiological and nonradiological contaminants of the stream.

Detailed information on the data-collection approach chosen, the analysis performed, and the assumptions used to arrive at the stated values is provided in this section under the heading "Data-Collection Approach." Data on the first 14 waste streams were arrived at by extrapolating information on stored waste from the RFP. The amount of plutonium and americium in each container and the method of generating the waste were taken from the stored waste information in the Clements (1982) report. The quantities of nonradiological contaminants that were calculated from the extrapolation procedure were derived by using information from the Kudera (1989) report. The information available for the other six waste streams (organic sludge, evaporator salts, uranium, and radiation sources waste streams) is provided in the applicable waste stream summary.

RFO-DOW-3H (Uncemented sludges)

- **Generation of the waste stream.** Wet sludge was produced by precipitation of aqueous process waste, such as ion-exchange effluent, distillates, and caustic scrub solutions. For the sorption of free liquids, Portland cement was added on top of the wet sludge in the drum, but a monolith did not result.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, Pu-241, and Am-241.

  Because most of this waste was generated by hydroxide precipitation, it is expected that the plutonium and americium exist as hydrated oxides, such as $PuO_2 \cdot 2H_2O$. If the sludge is dried, it would be expected to lose some or all of the water of hydration and exist as the oxide.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this stream are methylene chloride and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon).

Table 2-19. Waste streams originating at the Rocky Flats Plant.

Waste stream number	Description of waste
RFO-DOW-1H	Benelex and plexiglass
RFO-DOW-2H	Cemented sludges
RFO-DOW-3H	Uncemented sludges
RFO-DOW-4H	Paper, rags, plastic, clothing, cardboard, wood, and polyethylene bottles
RFO-DOW-5H	Concrete, brick
RFO-DOW-6H	Filters
RFO-DOW-7H	Glass
RFO-DOW-8H	Glovebox gloves
RFO-DOW-9H	Glove boxes, equipment (bottles, drill presses, etc.) pumps, motors, control panels, and office equipment
RFO-DOW-10H	Conduit, pipes, control panels, office equipment, and glass
RFO-DOW-11H	Nonmetal molds and crucibles
RFO-DOW-12H	Dirt, concrete, graphite, ash, and soot
RFO-DOW-13H	Resins
RFO-DOW-14H	Salts
RFO-DOW-15H	Organic sludge
RFO-DOW-16H	Depleted uranium
RFO-DOW-17H	Evaporator salts
RFO-DOW-18H	Enriched uranium
RFO-DOW-19H	U-233
RFO-DOW-20H	Radiation sources

The methylene chloride was used at the plant as a paint stripper. It was estimated to be present in this waste stream at a level of about 700 ppm. The Freon was used for the degreasing of metal. It was estimated to be present in this waste stream at a level of about 100 ppm.

RFO-DOW-4H (Combustibles)

- **Generation of the waste stream.** This stream consists of combustible materials such as paper, rags, plastics, cloth coveralls and booties, cardboard, wood, and polyethylene. Some of the waste was packaged in a damp or moist condition. This waste was generated during cleanup or normal operations and maintenance.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, Pu-241, and Am-241.

  The plutonium and americium in this waste are normally expected to be in oxide form. However, nitrates may be present on some of the damp or moist combustibles.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this stream are methylene chloride, 1,1,2-trichloro-1,2,2-trifluoroethane (Freon), carbon tetrachloride, and 1,1,1-trichloroethane.

  The methylene chloride was used at the plant as a paint stripper. It was estimated to be present in this waste stream at a level of about 750 ppm. The Freon, carbon tetrachloride, and 1,1,1-trichloroethane were used for the degreasing of metal. Freon was estimated to be present in this waste stream at a level of about 1,500 ppm, carbon tetrachloride at about 750 ppm, and 1,1,1-trichloroethane at about 2,000 ppm.

RFO-DOW-6H (Filters)

- **Generation of the waste stream.** This stream consists of asbestos or fiberglass filters in wood or aluminum frames and asbestos-type insulation, gloves, and fireblankets. Some Chemical Warfare Service (CWS)-type cylindrical filters are also in this waste stream. The waste was generated during normal operations, maintenance, and cleanup.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, Pu-241, and Am-241.

  Most of the plutonium and americium in this waste is expected to be in oxide form. However, nitrates may be present on the CWS filters.

RFO-DOW-7H (Glass)

- **Generation of the waste stream.** This stream consists of glass in the form of sample vials and bottles; lead-taped sample vials; ion-exchange columns; dissolver pots; laboratory glassware; glovebox windows (glass, plexiglas, or leaded glass); crushed or ground glass;

and borated raschig rings. The raschig rings were used in liquid storage tanks to minimize neutron multiplication and, therefore, reduce the chances of an accidental criticality.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, and Pu-241.

  Most of the plutonium in this waste stream is expected to be in the form of plutonium oxide. Some of the raschig rings and other glass types may have been exposed to plutonium nitrates, but the small amounts have probably been oxidized because of exposure to air.

RFO-DOW-8H (Glovebox gloves)

- **Generation of the waste stream.** This stream consists of glovebox gloves and aprons made from leaded rubber. The leaded rubber was used as shielding to minimize the exposure of workers to radiation.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, and Pu-241.

  Most of the plutonium in this waste is expected to be in the form of plutonium oxide. Some of the glovebox gloves may have been exposed to plutonium nitrates, but the small amounts have probably been oxidized because of exposure to air.

- **Principal nonradiological contaminants.** The principal nonradiological contaminant in this stream is lead. The lead is present as leaded rubber in glovebox gloves and aprons.

RFO-DOW-9H (Metals)

- **Generation of the waste stream.** This stream consists of metal waste such as gloveboxes, furnaces, lathes, ducting, motors, electronic equipment, power tools, hand tools, metal crucibles, and metal office equipment. The waste was generated from normal plant operations, maintenance work, and cleanup and renovation projects.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, and Pu-241.

  The plutonium in this waste is normally expected to be in the form of plutonium oxide. However, plutonium metal is probably the predominant composition of the plutonium on the metal crucibles.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this waste stream are methylene chloride, 1,1,2-trichloro-1,2,2-trifluoroethane (Freon), and lead.

  The methylene chloride was used at the plant as a paint stripper and was estimated to be present in this waste stream at a level of about 200 ppm. The Freon was used for the

degreasing of metal and was estimated to be present in this waste stream at a level of about 75 ppm. The lead is present mostly as shielding in gloveboxes and was estimated to be present at a level of about 2,000 ppm.

RFO-DOW-11H (Nonmetal molds and crucibles)

- **Generation of the waste stream.** This stream consists of graphite molds used in casting plutonium metal and small silicate-based ceramic crucibles used for chemical analysis of the carbon content of plutonium metal.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, and Pu-241.

  The plutonium in this waste is expected to be in the form of plutonium metal. There could be some oxide coating on the metal.

RFO-DOW-12H (Particulate waste)

- **Generation of the waste stream.** This stream consists of significant quantities of dispersible fines. The waste was generated from graphite crucibles, magnesium oxide crucibles, blacktop, concrete, dirt, and some wet combustible waste that contains noncombustible Oil-Dri.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Pu-238, Pu-239, Pu-240, Pu-241, and Am-241.

  Most of the plutonium and americium in this waste is expected to be in oxide form. Initially, very small pieces of plutonium metal may have existed on the crucibles, but they have probably been oxidized because of exposure to air.

- **Principal nonradiological contaminants.** The principal nonradiological contaminant in this stream is methylene chloride.

  The methylene chloride was used at the plant as a paint stripper. It was estimated to be present in this waste stream at a level of about 700 ppm.

RFO-DOW-15H (Organic sludge)

- **Generation of the waste stream.** This stream was produced from treatment of liquid organic waste generated by various plutonium and nonplutonium operations. The organic waste was mixed with calcium silicate to form a grease or paste-like material. No chemical reaction within the waste is expected to change the form of any of the organic constituents. Small amounts of Oil-Dri absorbent were usually mixed with the waste.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this waste stream are trichloroethene (trichloroethylene), carbon tetrachloride, 1,1,1-trichloroethane, and tetrachloroethene (tetrachloroethylene or perchloroethylene).

The carbon tetrachloride was mixed with Texaco Regal oil and used as a lathe coolant for the machining of plutonium. The 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene were all used for the degreasing of metal.

- **Information sources reviewed and used; assumptions and analysis.** The quantities of carbon tetrachloride in this waste stream were obtained by a review of the RFP Waste Management monthly reports for the appropriate time periods (Kudera 1987). These monthly reports contained data on the amount of lathe coolant (which was 40% carbon tetrachloride and 60% Texaco Regal oil) received for processing each month. These reports also listed the total volume of used oil, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene that was received by the waste treatment facility each month. However, no information was available to allow a further breakdown of the individual quantities of each of these chemicals.

  Because the quantities of these "other organics" are substantial, it is desirable to provide a best estimate of the individual amounts. ChemRisk (1992a) discusses the uses of these organics at the RFP and also provides annual quantities in a 1974 RFP harmful materials inventory. To estimate the quantities of 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene in this volume of "other organics," it was conservatively assumed that no used oil was present. It was also assumed that the ratios of 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene in this "other organic" were the same as their ratios in the 1974 harmful materials inventory at the RFP (ChemRisk 1992a). Because this method provides only an estimate of the relative amounts of each of the volatile organic compounds in the volume of "other organics," the percentages of each were rounded to 45%, 45%, and 10% when making the best estimates.

RFO-DOW-16H (Depleted uranium); RFO-DOW-18H (enriched uranium); RFO-DOW-19H (U-233)

- **Generation of the waste stream.** Depleted uranium operations consisted of casting, machining, rolling, and forming. The enriched uranium operations included recovery and purification processes in addition to the casting, forming, and machining. The main part of the purification was by a solvent extraction process. The RFP also reported sending 56 g of U-233 to the INEL in 1967 (Lee 1971). It is assumed that this U-233 was not mixed with the depleted or enriched uranium waste streams.

- **Principal radiological contaminants.** The principal radiological contaminants in the depleted uranium (approximately 0.2% U-235 by mass) waste stream are U-238, U-234, U-235, and U-236. These calculations are based on the mass fractions for the radionuclides in material type U-12 from the (EG&G Idaho 1985a).

  The principal radiological contaminants in the enriched uranium (approximately 93% U-235 by mass) waste stream are U-234, U-235, U-236, and U-238. The calculated compositions are based on the mass fractions for the radionuclides in material type U-38 from EG&G Idaho (1985a).

  The principal radiological contaminant in the U-233 waste stream is U-233 (Lee 1971).

RFO-DOW-17H (Evaporator salts)

- **Generation of the waste stream.** This waste stream consists of dried salt residue that was formed from concentrated evaporator sludge. Liquid effluents from the second stage of treatment of aqueous process waste and all other plant-generated liquid waste not requiring treatment were concentrated in solar evaporation ponds. The liquid was then pumped from the ponds to an evaporator, concentrated, and dried to form a salt residue. The approximate chemical makeup of the salt is 60% sodium nitrate, 30% potassium nitrate, and 10% miscellaneous.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this waste stream are sodium nitrate and potassium nitrate.

  The liquid effluents that were fed to this waste stream usually were dilute nitric acid solutions. The solutions that contained above-discard levels of plutonium were made basic with caustic solution to precipitate the plutonium as the hydroxide. The effluent from this precipitation contained sodium and potassium from the caustic solution and nitrate from the nitric acid solution. The concentration and evaporation of these solutions formed the sodium and potassium nitrates.

With the exception of the radiation sources waste stream, RFP waste does not contain activation products or fission products, so terms such as MAP and MFP are not encountered in the records for RFP waste.

2.4.7 Other Generators

The Generators. The remaining generators are referred to here as the "other generators." They include both offsite and other onsite (INEL) generators, and they contributed less than 10% of the volume of waste disposed of in the SDA.

Onsite generators (see Figure 2-1) include minor INEL contributors, such as the Auxiliary Reactor Area (ARA), CFA, D&D activities, PBF/Power Excursion Reactor facility (PER), and the RWMC itself as a waste generator.

ARA is located in the south-central part of the INEL and consists of four main areas: ARA-I, ARA-II, ARA-III, and ARA-IV. These areas were collectively called the Army Reactor Area until 1965, when the Army's programs at the INEL were phased out. ARA was originally built to house and support the SL-1 reactor, the Army Gas-Cooled Reactor Experiment (GCRE), and the ML-1 reactor. By the mid-1980s, D&D of some of the facilities was in progress, and the remainder of the facilities were essentially closed.

CFA is also located in the south-central portion of the INEL. Some of the facilities in use at CFA were built in the 1940s and 1950s to support and house Naval Gunnery Range personnel. These facilities have been modified continually over the last 40 years to meet the changing needs of the INEL. CFA currently operates as a centralized location to support the other INEL facilities, including administrative support, service shops, sanitary landfill, warehousing, security support, laboratory services, training, medical services, and receiving and storage.

The D&D of INEL nuclear facilities has been in progress as a separate function since 1975. D&D programs that contributed waste to the SDA through 1983 include D&D of the Army Re-Entry Vehicle site; the Boiling Water Reactor Experiment (BORAX)-V reactor area; the IET Facility; the LOFT reactor area; the Organic Moderated Reactor Experiment Facility; the S1-G reactor vessel; the Special Power Excursion Reactor Test (SPERT)-IV reactor building; and underground tanks, a liquid waste evaporator system, and a concrete pad at TAN.

The PBF area is located approximately 10 km (6 mi) northeast of CFA. This area originally contained reactors constructed for the SPERT experiments. Four SPERT reactors were built beginning in the late 1950s as part of an early investigation involving reactor transient behavior tests and safety studies on water-moderated, enriched-fuel reactor systems. All of the reactors have been removed, and most of the facilities have undergone D&D. The last of these reactors was placed on standby status in 1970. PBF began operations in 1972. PBF presently consists of the PBF reactor area (north of SPERT-I), PBF control area, Waste Engineering Development Facility (at the SPERT-II site), Waste Experimental Reduction Facility (at the SPERT-III site), and Mixed Waste Storage Facility (SPERT-IV).

The RWMC was established at the INEL in 1952 to accommodate the radioactive waste generated by laboratory operations. Minimal amounts of waste were generated directly by the RWMC and disposed of in the SDA. The waste consisted primarily of effluents from the decontamination of shipping and transportation equipment.

Offsite generators (other than the RFP) consisted primarily of commercial and government LLW generators that shipped waste to the SDA during the 4-year period from 1960 to 1963. During this period, the RWMC was designated by the AEC, predecessor agency to DOE, as a national disposal site for licensees that generated LLW. These generators are listed in Table 2-20.

Generation of the Waste. The other generators predominantly disposed of scrap metals and combustible materials that were radiologically contaminated. A variety of waste streams and processes were identified that contributed minor volumes of waste to the SDA. More than 100 waste streams have been identified for these generators. As many as six processes may have contributed waste to any one stream. Because these generators contributed less than 10% by volume of the overall waste to the SDA, it would be inappropriate to attempt to discuss each process in detail. Therefore, the discussions of the waste generation processes from these generators are general. Waste streams and associated processes that contribute significantly to the overall waste inventory are discussed in more detail.

Waste from ARA consisted primarily of radioactive contaminants from the short-term production and operation of the Army GCRE, the ML-1 reactor, the SL-1 reactor, and the radiochemistry laboratory. Solvents, thinners, acids, and mineral oils were routinely used, and waste was generated. However, all available information indicates that the nonradiological contaminants from ARA were not disposed of in the SDA.

Waste from CFA is from several facilities, past and present, including the CFA laundry, machine shops, maintenance shops, lead shops, laboratory facilities, sewage treatment facilities, and Radiological and Environmental Sciences Laboratory (RESL). Radioactive waste from CFA typically

Table 2-20. Commercial and government offsite generators who shipped waste to the Subsurface Disposal Area.[a]

American Electronics, Inc., Los Angeles, California
Atlas Foundry and Machine Co., Tacoma, Washington
Atomics International, Canoga Park, California
Babcock & Wilcox Co., Nuclear Facilities, Lynchburg, Virginia
Birdwell Division of Seismograph Services Corporation, Tulsa, Oklahoma
California Salvage Co., San Pedro, California
Colorado School of Mines, Research, Golden, Colorado

Dugway Proving Ground, Dugway, Utah
Fort Douglas, Utah, Commanding Officer, Salt Lake City, Utah
Fort Lewis, Washington, Commanding General Fourth Infantry Division, Washington
General Dynamics/General Atomics Division, San Diego, California
General Dynamics, Fort Worth, Texas
General Electric Co., Vallecitos Atomic Laboratory, Pleasanton, California
Department of Health, Education, and Welfare, Radiological Health Public Health Service, Washington, D.C.
Isotope Specialties Co., Burbank, California

Industrial X-Ray Engineers, Seattle, Washington
Laboratory of Nuclear Medicine and Radiological Biology, University of California, Los Angeles, California
Lawrence Radiation Laboratory, University of California, Berkeley, California
Marine Corporation Supply Center, Barstow, California
Memorial Hospital of Sheridan County, Sheridan, Wyoming
Metallurgical Engineers, Inc., Portland, Oregon
Nuclear Engineering Co., Pleasanton, California

Nuclear Power Field Office, Fort Belvoir, Virginia
Oregon Metallurgical Corporation, Albany, Oregon
PM-1 Nuclear Power Plant, Sundance AFS, Sundance, Wyoming
SAAMA, Kelly Air Force Base, Texas
Sacramento Signal Depot, Commanding General, Sacramento, California
Thiokol Chemical Corporation, Brigham City, Utah
U.S. Army Chemical Center, Maryland
U.S. Bureau of Mines, Albany, Oregon

U.S. Army Edgewood Arsenal, Maryland
U.S. Naval Radiological Defense Laboratory, San Francisco, California
University of Utah, Radiobiology Division, Department of Anatomy, Salt Lake City, Utah
University of Washington, Radiological Safety Division, Seattle, Washington
USARAL Support Command and Fort Richardson, Seattle, Washington
U.S. Nuclear Corporation, Burbank, California
Wah Chang Corporation, Albany, Oregon
Washington State University, Pullman, Washington

a. Other minor offsite generators that contributed waste to the SDA include Argonne National Laboratory-East from 1980 to 1983 and Battelle Northwest Laboratories in 1983.

includes contaminated combustibles, scrap metal, and nuclear radiation sources. Nonradiological contaminants from CFA were not routinely disposed of in the SDA.

Waste generated by D&D programs consists primarily of surface-contaminated metal, lumber, and soils. D&D operations concentrate on the dismantling and decommissioning of buildings and building components.

The PBF area contributed radioactive waste to the SDA from operations associated with the four SPERT reactors. This waste consisted primarily of metals, combustibles, and core and loop components. Minor volumes of nonradiological waste (solvents, resins, cleaning solutions, and acids) were included with waste shipments to the SDA.

Waste from the RWMC was generated over a 7-year period and consists primarily of radiologically contaminated materials (combustibles, soil, and plastic) associated with decontamination processes at the RWMC.

Commercial and government offsite generators contributed waste primarily as a result of radiological research. These contaminants in the waste were predominantly radionuclides with short half-lives. Nonradiological contaminants are not well documented, and they consist primarily of solvents and cleaning solutions.

ANL-E waste is from programs including fundamental research in physical, biomedical, and environmental sciences and from energy research and development.

Battelle Northwest Laboratories (BNL) waste is from radionuclide research and plutonium studies. Only one shipment from BNL was received, and it occurred during 1983.

General Availability of Information. Information concerning waste streams from the other generators is limited to a few reports that often do not describe the processes that generated the waste. This is particularly true for nonradiological contaminants in the waste and for the physical and chemical forms.

Information concerning types and volumes of waste was derived from several types of sources. These sources included process information, previous reports, shipping records, waste disposal practices, interviews with personnel familiar with waste streams from the other generators, and the process knowledge of data gatherers familiar with specific facilities and their waste streams.

For the various generators, the sources of information listed in Table 2-21 were used.

Additional related reports that were reviewed but not used include Arrenholz and Knight (1991), Dolenc (1980), EG&G Idaho (1985b), McCusker (1986), Plansky and Hoiland (1992), Smith (1978), Smith and Hine (1982), and Yrene and McCusker (1986). These reports were not used, either because the data included in the reports were also included in the reports listed in Table 2-21 or because the reports do not contain useful data for this evaluation.

Data-Collection Approach. The data-collection approach taken to evaluate the other generators involved the following steps. Available reports discussing radiological and nonradiological

Table 2-21. Sources of information used for the other generators.

Generator	Documents	Additional sources
ANL-E	Kee (1982)	Shipping records
ARA	EG&G Idaho (1986)	Shipping records, interviews
BNL	—	Shipping records, interviews
CFA	EG&G Idaho (1986), Hiaring (1993)	Shipping records, interviews
D&D programs	Hine (1980), Huntsman (1979), Schoonen (1984), Smith (1979), Smith (1980), Smith (1983)	Shipping records, interviews
LOFT	EG&G Idaho (1986)	Shipping records, process information
Offsite generators	Clements (1979), Clements (1980b)	Shipping records
PER/PBF	EG&G Idaho (1986)	Interviews, shipping records, process information
RWMC	EG&G Idaho (1986)	Interviews, shipping records

waste generation information, waste disposal practices, and facility process information were reviewed. RWMIS printouts were obtained by generator (for offsite generators) or building number (for INEL facilities). The original shipping manifests were located for each shipment and compared against RWMIS and the reports. Personnel familiar with the waste generation process were interviewed. For example, operator interviews were used to obtain additional waste stream information for many of the CFA and PBF/PER generators. Past facility experience and process knowledge were used, in part, for determining waste streams at ARA and LOFT. Discrepancies in data collected from more than one source were identified and discussed. For generators producing very small waste volumes or activities, including BNL and many of the CFA generators, the evaluation was based only on shipping records.

For MAP and MFP entries, the assumed radionuclide breakdown varied by waste stream. Unidentified beta-gamma and unidentified alpha entries were extremely small in radioactivity.

Description of Waste Streams. The waste from the other generators was divided into 111 streams (see Table 2-22).

The 12 most important waste streams from the other generators are discussed here. For each of these streams, the discussion tells how the stream was generated, the principal contaminants in the stream, the specific information sources reviewed and used, and the assumptions and analysis used to estimate the quantities of the contaminants.

Table 2-22. Waste streams originating from other generators.

Waste stream number	Description of waste
ALE-ALE-1H	Building rubble, electric wires, piping, machinery, radioactive tracers and sources, glass, gloves, paper, filters, and vermiculite
ARA-601-1H	One each, Davis water filter units
ARA-602-1H	Waste from the SL-1 cleanup: a 1,000-gal tank, a demineralizer with resin, various building materials, pipes, soil, wire, concrete, insulation, etc.
ARA-602-2H	Low levels of items listed as "scrap" and "rad waste not otherwise specified (NOS)" that were taken from the ML-1 site during cleanup. There is a small amount of paper and wood.
ARA-602-3H	Hot cell waste consisting of some fuel residue. Some metals (copper, cadmium, stainless steel, and aluminum); some soil; HEPA filters; and cleanup supplies (rags, paper, mops, etc.).
ARA-606-1H	Contaminated soil and scrap building material
ARA-607-1H	Depleted uranium and U-238 milling chips
ARA-608-1H	<0.1 Ci UO_2; tank, pump, valves, gauges, wire scrap metal, sludge NOS, concrete masonry, and asphalt gravel
ARA-616-1H	ML-1 and GCRE waste consisting of various scrap metals (stainless steel, silver, aluminum, iron, potassium, and lead); resin; burnables; sludge; and some boric acid crystals
ARA-626-1H	Some fuel scraps, waste from disassembly of facilities, and hot cell waste
ARA-627-1H	Plastic bags, brick, HEPA filters, scrap, glove boxes, and fuel (U-235 and U-238)
BNL-BNL-1H	Primary operations at BNL involved producing plutonium from U-238 *(no other information available)*
CFA-601-1H	Miscellaneous scrap metal, gas cylinders, lead batteries, insulated wire, glass, soil, aluminum, beryllium, cadmium, and general cleanup waste

Table 2-22. (continued).

Waste stream number	Description of waste
CFA-605-1H	Lead slag/floor sweepings. One metal hood, some stainless steel and some plastic vials containing graphite. There is some natural and some depleted uranium alloyed with aluminum and zirconium.
CFA-606-1H	One safe from AEC security and some metal samples that were found on the shuttle bus
CFA-609-1H	1.1 m^3 (40 ft^3) of contaminated lumber and one camera
CFA-610-1H	Undershirt, two pairs of pants, hat, shirt, and lunchbox. Also, mercury batteries and contaminated mud.
CFA-611-1H	Miscellaneous items: radios and other items confiscated as a result of a security investigation
CFA-613-1H	Soil and paper
CFA-616-1H	Soil from auger sampling
CFA-617-1H	Plastic, paper, and rags
CFA-626-1H	Unknown—MFP
CFA-633-1H	Basic trash—metal, wood, gravel, sand, etc.
CFA-638-1H	Two shielded casks with a Co-60 source in each
CFA-639-1H	Wood and metal scrap with beryllium contamination
CFA-640-1H	Machine shop waste (various types of metal chips and cleanup materials). Batteries and a cabinet from SL-1. Some stainless steel and some lead. (The batteries from SL-1 contained acid.)
CFA-646-1H	Radioactively contaminated combustibles (paper, cloth, wood, etc.)
CFA-646-2H	HF and HNO_3 liquid waste
CFA-649-1H	Waste NOS

Table 2-22. (continued).

Waste stream number	Description of waste
CFA-654-1H	Scrap metals (steel, beryllium, and lead); zirconium; depleted uranium; sewer sludge; machine coolant; two radium sources; weeds; and combustibles (paper, rags, etc.)
CFA-659-1H	Plastic and cloth
CFA-660-1H	Metal, wood
CFA-665-1H	Two truck beds, three trailers, one forklift, one straddle carrier, some tires and wheels, an air compressor, and some wood
CFA-666-1H	U-235, contaminated waste from simulated fire
CFA-666-2H	Depleted uranium turnings in mineral oil
CFA-667-1H	Clothing, plastic bags, and sweepings
CFA-667-2H	Contaminated lead
CFA-669-1H	Combustibles, dirt
CFA-674-1H	Laboratory waste contaminated with P-32, U-235, and U-238; excess property (furniture, machinery, valves, boxes, wire, and filters); and combustible waste
CFA-683-1H	Contaminated crane, two pickups, tanker, trailer, traveler wheels, scrap metal, and some wood
CFA-684-1H	Irradiated steel specimens, rags, paper, plastic bags, and some graphite
CFA-685-1H	Metal, paper, and cloth (oil soaked)
CFA-687-1H	Scrap metal and lead
CFA-690-1H	Combustibles, animal carcasses and feces, scrap metal, sources, sand, and gravel
CFA-691-1H	Sewage plant sludge, plant waste, wood, and metal
CFA-698-1H	Beryllium samples that were contaminated by ATR, primary coolant

Table 2-22. (continued).

Waste stream number	Description of waste
CFA-766-1H	Sludge tank sludge, soil, piping, cans, and wood
CFA-CFA-1H	Laundry waste, general plant waste, graphite, stainless-steel tubes and samples, Mark '87 specimens, rubber fabric hose, and some steel backhoe parts
CFA-EBR-1H	Contaminated soil, concrete, bricks, piping, components, metal scrap, rags, mops, filters, wooden pallets, and plastic wrapping
CFA-EFS-1H	Contaminated sod, wood, and blotting paper
CFA-ZPR-1H	Various rip-out materials, including contaminated tubing, a uranium film sampler, structural metals, concrete, rags, paper, and plastic
D&D-ARV-1H	Wood and scrap metal
D&D-BOR-1H	Soil
D&D-IET-1H	Heat exchangers, pump cases, pump diffuser, and impeller
D&D-LOF-1H	Cloth, paper compactibles
D&D-LOF-2H	Paper, poly, rags
D&D-LOF-3H	Paper, cloth, compactibles
D&D-OMR-1H	Metal, concrete, soil
D&D-S1G-1H	Decontaminated reactor vessel and processing equipment, components, and piping
D&D-SPT-1H	Piping, tanks, valves
D&D-TAN-1H	PM-2A underground tanks, PM-2A liquid waste evaporator system, and TSF-3 concrete pad
LOF-650-1H	Combustibles (paper, cloth, wood, etc.)
OFF-AEF-1H	Scrap metal, combustibles, glass, concrete
OFF-AEI-1H	Radiation sources, laboratory waste, and solidified Ce-144/Cl_3 solution

Table 2-22. (continued).

Waste stream number	Description of waste
OFF-AFM-1H	Co-60 source
OFF-ATI-1H	Irradiated fuel and chemical byproducts from nuclear reactor research
OFF-BWC-1H	Empty stainless-steel fuel rods
OFF-BWD-1H	Miscellaneous laboratory equipment
OFF-CSC-1H	Laboratory equipment and animal carcasses and feces
OFF-CSM-1H	Magnesium fluoride slag with 1% natural uranium, steel metallic salts and silicates, miscellaneous laboratory waste
OFF-DPG-1H	Animal waste and laboratory waste
OFF-FLW-1H	Radioactive electronic tubes
OFF-GDA-1H	Fuel fabrication items, laboratory equipment, activated metal, and irradiated fuel
OFF-GDW-1H	Waste NOS
OFF-GEC-1H	Core, reactor vessel, and loop components
OFF-GEO-1H	Waste NOS
OFF-HEW-1H	Radium-contaminated laboratory waste
OFF-ISC-1H	Magnesium-thorium scrap, laboratory equipment, and sources
OFF-IXE-1H	Radiation sources
OFF-LRL-1H	Biological waste
OFF-LRL-2H	Concrete, bricks, and asphalt
OFF-MCS-1H	Electronic tubes and metascopes
OFF-MEI-1H	Probably sources
OFF-MHS-1H	Thirty-nine Co-60 wires sealed in concrete

Table 2-22. (continued).

Waste stream number	Description of waste
OFF-NEC-1H	Aluminum heat exchanger and waste containing U-235 and U-238
OFF-NMR-1H	Biological waste
OFF-NPF-1H	Control rods
OFF-OMC-1H	Paper, graphite, clothing, steel, copper crucibles, and acid carboy
OFF-PM1-1H	Resin storage tank, cement, and empty tank
OFF-SAM-1H	Missile structural components, jet engine parts, fragments of fuel tanks, paper, and ash
OFF-SAM-2H	Reactor shield, miscellaneous metals (magnesium alloy, copper, tin, aluminum, and stainless steel); insulation; rubber; plastic; paper; glass; wire; dirt; wood; concrete; and ash
OFF-SSD-1H	Radio transmitting and receiving sets, switchboards, tubes, plastic, electric instruments, and cobalt resinate
OFF-TCC-1H	Rags, wipes, tape, concrete, graphite, and solvent
OFF-UAC-1H	Radioactive waste packed in cement
OFF-UBM-1H	Ore processing waste [includes rare earth elements (U_3O_8, Fe_2O_3, thorium oxide, uranium chlorides, and iron oxides)]
OFF-UEA-1H	Paper, disposable syringes, glass, plastic containers, and animal carcasses
OFF-UNR-1H	Laboratory waste (paper, wood, glassware, empty bottles, etc.); Co-60 sources; Sr-90 sources; and H-3
OFF-UOU-1H	Biological waste
OFF-UOW-1H	Animals, animal tissue, isotopic solutions, evaporated residues, paper, syringes, clothing, laboratory glassware, planchets, benzene, carbon tetrachloride, methyl alcohol, and other biomedical waste
OFF-USC-1H	Resin-filled demineralizers

Table 2-22. (continued).

Waste stream number	Description of waste
OFF-USN-1H	Animal carcasses, waste paper towels, glassware, tools, and similar laboratory items
OFF-WCC-1H	Paper rags, furnace coke, carbon baffles, wax brick refractory, and small hand tools
OFF-WSU-1H	Bird, animal, and crayfish carcasses; kim-wipes; paper towels; gloves; aluminum; and stainless-steel planchets
PER-601-1H	Combustibles (paper, cloth, wood, etc.)
PER-612-1H	Glove box, vacuum pump, air conditioner, capsule, and radioactive source
PER-613-1H	Core structure components, reactor vessel, and loop components
PER-617-1H	Irradiated and unirradiated fuel
PER-620-1H	Paper, cloth, wood, resin, insulation, batteries, concrete, asphalt, and radioactive sources
PER-623-1H	Irradiated fuel powder and pellets
PER-ORM-1H	Paper, cloth, wood, barrels of Santo-R wax, and empty barrels
WMC-WMC-1H	Soil, pond sediment, scrap metal, and equipment

D&D-S1G-1H

- **Generation of the waste stream.** This waste stream consisted of the waste generated from D&D of the S1-G reactor vessel at TRA in 1983. The S1-G reactor vessel was comprised of three concentric cylinders of heavy-wall steel designed for pressure containment. It contained solidified sodium coolant and weighed in excess of 100 tons. The purpose of the D&D operations was to remove the metallic sodium from the vessel and dispose of the intact vessel in the SDA.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are H-3, Co-60, Ni-63, Fe-55, Ni-59, and Nb-94. All sodium was removed from the reactor vessel before disposal. The reactor vessel was sealed before disposal; however, 3,300 Ci of H-3 remained in the vessel.

- **Information sources reviewed and used.** Table 2-21 and the list of additional related reports identify reports reviewed and used. Additional information concerning this waste stream was obtained from discussions with Richard Meservey, former manager of the D&D program, and from shipping records.

- **Assumptions and analysis.** Based on interviews and available reports, few nonradiological contaminants were included in the D&D program waste streams disposed of in the SDA. No assumptions were made concerning the radiological contaminants in the waste streams.

OFF-AEF-1H

- **Generation of the waste stream.** Waste from the AEC San Francisco Operations Office, now NRC Region V, originated from an AEC cleanup operation of the Coastwise Marine Disposal Company warehouse located in Long Beach, California. Coastwise was a radioactive waste disposal company and serviced a number of commercial and government facilities. Information is unavailable on the processes and waste streams of these facilities. The AEC permanently revoked the Coastwise license in 1961 and assumed responsibility for disposal of the Coastwise waste. Because the majority of solid waste stored at Coastwise had previously been packaged for ocean disposal, the nature of the waste received at the INEL is uncertain.

- **Principal radiological contaminants.** The principal radiological contaminants listed in disposal records for this waste stream include Co-60, Ra-226, and Sr-90.

- **Information sources reviewed and used.** Table 2-21 and the list of additional related reports identify reports reviewed and used. Additional information concerning this waste stream was obtained from shipping records.

- **Assumptions and analysis.** Reports on the operations and processes associated with this generator did not quantify the types of contaminants in the waste stream with precision. MFP was assumed to be Sr-90 for this generator based on a lack of information to determine a further breakdown. Because shipping records give only a total radioactivity

and a list of radionuclides, the total radioactivity was divided equally among Co-60, Ra-226, and Sr-90. According to available reports, nonradiological contaminants were not routinely stored or disposed of by Coastwise. Consequently, nonradiological contaminants were assumed not to be part of the waste stream.

OFF-ATI-1H

- **Generation of the waste stream.** Waste received from Atomics International Division, Rockwell International, Canoga Park, California, was derived from research and development, design, construction, and testing of several nuclear reactors and associated systems. Among these were the series of Systems for Nuclear Auxiliary Power (SNAP) reactors, the Sodium Reactor Experiment (SRE), the Hallam reactor, and the Piqua reactor. The SNAP reactors were fueled with hydrided uranium-zirconium alloy and were NaK-cooled. The SRE cores were fueled either by thorium-uranium alloy or unalloyed uranium and were NaK-cooled. The Hallam reactor was fueled by uranium-molybdenum or uranium carbide and was sodium-cooled. The Piqua reactor was fueled with a uranium-molybdenum alloy and cooled with an organic mixture of terphenyls. A majority of the waste received at the INEL from this generator was derived from operations associated with the SNAP and SRE reactors.

- **Principal radiological contaminants.** The principal radiological contaminants listed for this waste stream include Cs-137, Pu-239, U-235, U-238, and U-234.

- **Information sources reviewed and used.** Table 2-21 and the list of additional related reports identify reports reviewed and used. Additional information concerning this waste stream was obtained from shipping records.

- **Assumptions and analysis.** Reports on the operations and processes associated with this generator did not quantify the types of contaminants in the waste stream with precision. Uranium radionuclides were divided into the appropriate percentages based on the enrichment curves for uranium. MFP were converted to Cs-137 for this waste stream based on the suite of radionuclides listed in disposal records and on the generation processes. Based on available reports, nonradiological contaminants could be included in the waste stream, but typically they were sent elsewhere for disposal. Nonradiological contaminants mentioned in the report, but for which disposal at the INEL is in question, are listed with unknown quantities.

OFF-ISC-1H

- **Generation of the waste stream.** Waste generated from the now-closed Isotope Specialists Co., Burbank, California, consisted of wipes, gloves, glassware, etc., associated with radionuclide labeling operations.

- **Principal radiological contaminants.** The principal radiological contaminants in this waste stream are Co-60, Ra-226, Cs-137, and Th-232.

- **Information sources reviewed and used.** Table 2-21 and the list of additional related reports identify reports reviewed and used. Additional information concerning this waste stream was obtained from shipping records.

- **Assumptions and analysis.** Only four sentences from a single report could be located describing this generator and associated waste streams; consequently, detailed quantification of the waste stream is impossible. A magnesium and thorium alloy is reported to have been in the waste stream disposed of at the INEL. The volume of the alloy was estimated because quantities are not given. Seventy-one percent of the total volume of the shipment was estimated to represent the metal, excluding the box volume, based on assumptions concerning empty space in the containers.

OFF-USN-1H

- **Generation of the waste stream.** The waste generated from the U.S. Naval Radiological Defense Laboratory, San Francisco, California, consisted of radiologically contaminated animal carcasses, paper, wood, glassware, empty bottles, etc. This waste was generated from studies of the effects of fallout, instrumentation tests, metabolic studies, radionuclide uptake and retention studies, chemical separations, and decontamination studies.

- **Principal radiological contaminants.** In descending order of abundance, the principal radiological contaminants in this waste stream are Cs-137, Co-60, Po-210, Ra-226, Sr-90, Ir-192, Ba-137, Sb-124, Tm-170, Y-90, and C-14.

- **Information sources reviewed and used.** Table 2-21 and the list of additional related reports identify reports reviewed and used. Additional information concerning this waste stream was obtained from shipping records.

- **Assumptions and analysis.** Radionuclides in this waste stream are well documented in reports and on shipping records. No assumptions were made concerning the radionuclide waste stream. Reports indicate that animal carcasses were preserved in formaldehyde before shipment. The volume of formaldehyde included in the waste stream was estimated to be 5.5% of the volume that contained carcasses. Reports mention that nitric acid was used in this process. However, the acid is not believed to have been disposed of with the waste shipped from this generator.

CFA-640-1H

- **Generation of the waste stream.** This waste stream was derived from a machine shop at CFA. Reports do not specify details on the waste stream or the processes that generated the waste. Based on shipping records and what information is available in reports, the waste consisted of radioactively contaminated metal filings, chips, stainless steel, lead, and cleanup materials. In addition, the waste included batteries and a contaminated filing cabinet from the SL-1 reactor area.

- **Principal nonradiological contaminants.** The principal nonradiological contaminants in this stream are lead and a small quantity of sulfuric acid.

- **Information sources reviewed and used.** Table 2-21 and the list of additional related reports identify reports reviewed and used. Additional information concerning this waste stream was obtained from shipping records.

- **Assumptions and analysis.** Lead was mentioned as a constituent of each shipment. Volumes of the lead were not given, so an assumption was made that the lead accounted for 65% of all shipment weights. Sulfuric acid was assumed to be present in batteries that were disposed of. It was assumed that 1 L (0.3 gal) of sulfuric acid is contained in each battery.

  Radionuclides in this waste stream include MAP and MFP, and they account for less than 1 Ci for the entire stream. MAP were assumed to be all Co-60, and MFP were assumed to be Sr-90 in the absence of evidence to determine a distribution.

CFA-687-1H

- **Generation of the waste stream.** This waste stream was derived from the Lead Shop at CFA. Radioactively contaminated lead was sized, packaged, and shipped to the RWMC for disposal. Other contaminated scrap metals, dirt, and soil were included with the lead shipments.

- **Principal nonradiological contaminants.** The principal nonradiological contaminant in this stream is lead.

- **Information sources reviewed and used.** Table 2-21 and the list of additional related reports identify reports reviewed and used. Additional information concerning this waste stream was obtained from shipping records.

- **Assumptions and analysis.** Lead was mentioned as a constituent of each shipment. Volumes of the lead were not given; however, shipments of waste to the RWMC included lead with soil, dirt, and other scrap metals. Based on the composition of the waste stream, an assumption was made that the lead accounted for one-half of all shipment weights.

  Radionuclides in this waste stream include MAP and MFP, and they account for less than 1 Ci for the entire stream. MAP were assumed to be all Co-60, and MFP were assumed to be Sr-90 in the absence of evidence to determine a distribution.

PER-601-1H, PER-612-2H, PER-613-1H, PER-620-1H, PER-ORM-1H

Several waste streams from PER (PER-601-1H, PER-612-1H, PER-613-1H, PER-620-1H, and PER-ORM-1H) were important contributors to the inventory of certain nonradiological contaminants. These waste streams were derived primarily from cleanup of reactor components at the SPERT reactors and contained 2-butanone and toluene. These contaminants were determined to have been shipped to the RWMC on rags and wipes used for cleanup. It is likely, however, that these

contaminants volatilized to a large extent before disposal. An additional contaminant of importance in the waste streams from PBF is silver. The silver waste stream was derived from the SPERT-IV facility and originated from silver zeolite. Silver was routinely recovered when silver prices were high in the early 1980s. Based on interviews with operators of the facility, an estimate was made of the silver that was not recovered and that was disposed of in a glass matrix. Other nonradiological contaminants of importance in this stream are antimony and chromium.

2.4.8 Waste Disposed of on Pad A

The Generators and Rationale for Separate Reporting. From 1972 through 1978, waste suspected of containing TRU radionuclides in concentrations less than 10 nCi/g was disposed of aboveground on Pad A in the SDA (see Section 1.2 and Figure 1-2). In the HDT, this waste was grouped into two waste streams: stream PDA-RFO-1A consists of the Pad A waste that was shipped from the RFP, and stream PDA-INEL-1A consists of the remaining Pad A waste, which was shipped from several INEL facilities.

In the HDT, the information on the Pad A waste was compiled separately from the waste disposed of elsewhere in the SDA using the particular stream designators given above. The waste stream designators begin with the letters "PDA" and include the suffix "A," both of which refer to the Pad A disposal location. This method allows easy reporting of waste on Pad A separately from the other waste. The method does not imply that Pad A was a generator of waste, only that Pad A was a separate disposal location.

The total amount of waste from RFP can be determined by adding the stream PDA-RFO-1A to the sum of all streams that begin with "RFO-." Because the stream PDA-INEL-1A includes waste from several generators at the INEL, the HDT data cannot be used to assign that waste to the individual generators that produced it.

Whenever total contaminant quantities are provided in this report, the waste on Pad A is included in the inventory, unless otherwise stated.

Description of Waste Streams. The Pad A waste was divided into two waste streams (see Table 2-23). Both streams are discussed in detail below. For each of these streams, the discussion tells how the waste was generated, the principal contaminants in the stream, and the specific information sources reviewed and used.

Table 2-23. Waste streams disposed of on Pad A.

Waste stream number	Description of waste
PDA-RFO-1A	Evaporator salts
PDA-INEL-1A	Fuel production scrap and miscellaneous waste

PDA-RFO-1A (Evaporator salts)

- **Generation of the waste stream.** Section 2.4.6 discusses RFP waste and the generation of this waste stream during the time when it was buried belowgrade (from the inception of the stream in 1967 through 1972). The generation of the stream was essentially unchanged during the time it was disposed of on Pad A (from 1972 through 1978).

- **Principal Radiological Contaminants.** The principal radiological contaminants in this waste stream are U-238, U-234, and U-235.

- **Principal Nonradiological Contaminants.** The principal nonradiological contaminants in this stream are sodium nitrate and potassium nitrate.

- **Information Sources Reviewed and Used.** The information used was taken from RWMIS and from Halford et al. (1993).

PDA-INEL-1A (Fuel production scrap and miscellaneous waste)

- **Generation of the waste.** This waste stream was generated by a variety of experiments and processes at several generators involving very small activities of plutonium and uranium. Much of the waste was generated from processes involving unirradiated fuel.

- **Principal Radiological Contaminants.** This waste stream contains minute activities of plutonium and uranium.

- **Information Sources Reviewed and Used.** The information used was taken from RWMIS and from Halford et al. (1993).

2.5 Data Qualification Process

As shown in Figure 2-2, after the waste information for each generator was collected and entered onto data forms (one form for each waste stream), the information was subjected to a qualification process. That process is described briefly here.

Completed draft forms were logged in at a central point, and copies were reviewed by a three-person committee. One of the three people was knowledgeable about the physical, chemical, and radiological nature of the waste; another was an experienced risk assessor responsible for BRA activities; and the third was a statistician responsible for the treatment of uncertainty on the task. The completed draft forms were reviewed for completeness, clarity, consistency, reasonableness of assumptions, use of appropriate scientific units, possible duplication or overlap of coverage with forms completed for other waste streams, and compatibility with the structure of the database.

The committee members discussed their comments with the data gatherer who had prepared the draft forms. After agreement was reached on resolution of the comments, the original preparer made any necessary revisions to the forms.

The forms were then relogged in at the central point and transmitted to database personnel for entry. All data entered into the database (discussed in Section 2.6) were independently checked for correct entry. During data entry, several validation tables were used to ensure that only valid information was entered into several data fields. The validation tables contain prespecified "acceptable" values for the following types of information (data fields): nuclide, chemical name, Chemical Abstract Services (CAS) number, generator, building, etc. As a final check, the database printouts were then reviewed by the data gatherers who had completed the original forms.

The information in this report, including the waste inventory printouts, underwent peer review by technical, program management, regulatory compliance, and waste generator personnel.

2.6 Contaminant Inventory Database for Risk Assessment

A convenient method was needed to use the large body of data captured on the data forms for the HDT and the companion study (Lockheed 1995). Therefore, the Contaminant Inventory Database for Risk Assessment (CIDRA) database was created to manage the data gathered in both studies.

All data contained in CIDRA originated from completed data forms. Appendix A provides a blank version of the forms.

The CIDRA application was created in FoxPro and is accessible in dBASE.

Textual information captured in the database can be aggregated over different fields in the database (e.g., by waste stream or by generator). However, query and sort capabilities on the text fields are limited. This information was electronically captured to maintain a record of how the waste stream information was obtained and other pertinent details about the waste stream. The data tracking form is hierarchical—each subsequent section of the form contains more detailed information about a waste stream inventory.

The CIDRA report software application was developed to support reporting. The application can produce the following set of standard reports:

- Hazardous chemicals (Part C) data by various groupings [e.g., waste stream, generator(s)]
- Radionuclides (Part D) information by various groupings [e.g., waste stream, generator(s)].

The information in these reports consists of the quantities and respective units of radiological and nonradiological contaminants.

Report generation is augmented by an algorithm that was developed to perform simplified decay calculations on the radionuclides. The user may specify any date to which decay is calculated, and CIDRA produces a data set with the decayed quantities.

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